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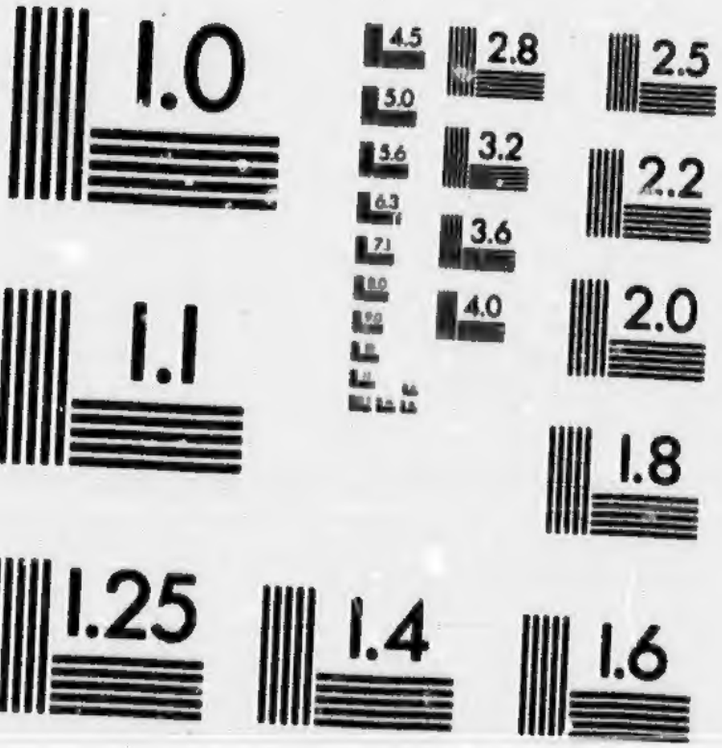

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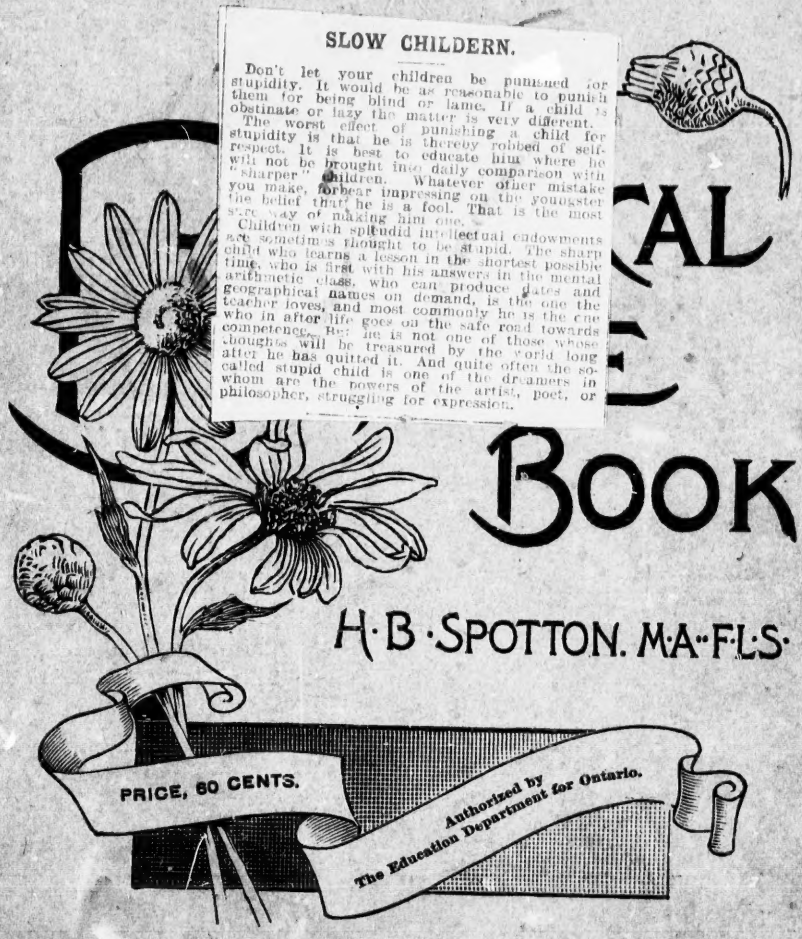
For the Junior and Senior Leaving Examinations.


SLOW CHILDERN.
Don't let your children be punished for stupidity. It would be as reasonable to punish them for being blind or lame. If a child is obstinate or lazy the matter is very different.
The worst effect of punishing a child for stupidity is that he is thereby robbed of self-respect. It is best to educate him where he will not be brought into daily comparison with "sharper" children. Whatever other mistake you make, forbear impressing on the youngster the belief that he is a fool. That is the most sure way of making him one.
Children with splendid intellectual endowments are sometimes thought to be stupid. The sharp child who learns a lesson in the shortest possible time, who is first with his answers in the mental arithmetic class, who can produce dates and geographical names on demand, is the one the teacher loves, and most commonly he is the one who in after life goes on the safe road towards competence. He is not one of those whose thoughts will be treasured by the world long after he has quitted it. And quite often the so-called stupid child is one of the dreamers in whom are the powers of the artist, poet, or philosopher, struggling for expression.

CAL

BOOK

H·B·SPOTTON. M.A·F.L.S·

PRICE, 60 CENTS.

Authorized by The Education Department for Ontario.

THE W. J. GAGE COMPANY (LTD.)
TORONTO.

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HIGH SCHOOL

BOTANICAL NOTE BOOK:

PART II.

FOR THE JUNIOR AND SENIOR LEAVING EXAMINATIONS

—BY—

H. B. SCOTTON, M.A., F.L.S.

PRINCIPAL OF HARBORD STREET COLLEGIATE INSTITUTE, TORONTO.

Authorized by the Education Department for Ontario.

Price, 60 Cents

THE W. J. GAGE COMPANY (LTD.),

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PREFACE.

This book is designed to meet the wants of candidates for the Junior and Senior Leaving Examinations of the Ontario Education Department. In addition to the matter of Part I. it contains a brief account of the minute structure of plants, some practical hints for carrying on microscopic work, descriptions of certain cryptogamous types, and a few illustrations of the Bean and the Maize, selected from Sachs' Botany and Professor Howes' valuable Atlas of Biology.

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ON THE MANAGEMENT OF

ELEMENTARY CLASSES IN BOTANY.

THE following suggestions are offered in the hope that they may be found helpful to those who are beginning the work of teaching Botany, as well as to the young student. The writer, mindful of the difficulties and perplexities which he has himself often had to encounter, makes no apology for thus presenting what appear to him to be the chief essentials to success in this department of school work. It goes without saying that no written instructions can ever make a successful teacher where natural enthusiasm is wanting, but it is equally true that the young enthusiast may derive some benefit from the larger experience of others; and while the intelligent and active teacher will not slavishly follow the details of any method, but will be quick to avail himself of any legitimate device which will serve his purpose, still there are broad principles upon which those who have had practical experience will probably agree. In the following remarks an attempt is made to outline the course of a year's work, which it is thought will be found practicable in any High School.

When to begin Botanical Work.—A good deal might be said in favor of beginning our botanical work in the spring. At that time, when nature is awaking from the torpor of winter, and the first leaves and flowers are unfolding, it is especially delightful to ramble abroad. Then, perhaps more than at any other time, the youthful mind is attracted by the forms of the vegetable world, and is prepared to enter upon the systematic study of them with more than ordinary enthusiasm. And if it were possible to continue through the summer the botanical work begun in the spring, doubtless the most satisfactory results would be obtained. There is, however, the break caused by the long vacation, during which teacher and pupils are separated and school work generally abandoned, so that when classes are resumed in September the work of the spring has to be gone over again, with the disadvantage of having, in most cases, new pupils as well as old ones to deal with. On the whole, therefore, as the school year begins in September, and a general re-organization of classes then takes place, it seems most advantageous to begin the botanical work at that time. During September and October an abundant supply of material is available, with the advantage also of access to fruits and seeds af all kinds, as well as flowers. It is exceedingly desirable that during this period, when fresh plants can be had for examination, the botanical lessons should be frequent. If a short lesson could be given every day at this time surprising progress would be made in a few weeks. When summer has passed by, and work has to be confined to such material as has been collected for winter use, the lessons need not be given so often; probably twice a week would be found quite sufficient. Then, in the spring, when field work can be resumed, the lessons may again be increased in frequency for a time.

How to begin.—Assuming, then, that the botanical work is commenced in September, the next question to consider is how to carry on the work of the class so as to give the subject its highest educational value. Botany is essentially a science of observation. One of its very highest uses as a factor in education is that it trains the eye to habits of accuracy. But, in order to

receive this benefit, it is essential that the pupil should be brought into contact with the forms which are the objects of study; that he should handle them and view them for himself; that he should by personal inspection, ascertain their habits, and by visiting their haunts learn the situations in which they flourish best. Undoubtedly, then, the first essential in giving a lesson is that every member of the class should have before him a specimen of the plant, or part of plant, which is to be the subject of the lesson. Then the teacher will direct attention to the different organs, naturally in the order of development of the organs themselves; first to the root, then to the stem, then to the leaves, and finally to the flower. In a first lesson it would not be amiss to make a superficial examination of the entire plant, rapidly and briefly discussing the nature and use of each part, but avoiding as far as posssible the use of technical terms. The chapter on the Buttercup, as given in the text-book, really affords material for several lessons. Each teacher must, however, be guided by the time at his disposal and the circumstances of his class as to how much ground he will attempt to cover at one time. Some of the plants described in the text-book as, for instance, Hepatica and Marsh Marigold, will not be available in the autumn. This, however, is a matter of comparatively little consequence, as others can be substituted. In fact, after one plant, such as Buttercup, has been thoroughly understood, almost any other dicotyledonous plant may be taken up and compared with it. The order followed in the text-book is a good one, because the pupil is led by degrees from the study of floral forms in which all the parts are present but entirely disconnected, to others showing various complications and irregularities; but the judicious teacher will readily supplement the work of the text-book by the use of material which he will find in abundance everywhere about him. Let him keep in view the series of facts which it is essential that the class should know, and he may use any material which would enable the class to discover those facts from personal observation.

How to conduct a Lesson.—If the class is a large one, it will economize time to have the observations made simultaneously. Suppose the Red Maple is the subject of the lesson, which of course in this particular case must be given in the spring. The class having observed that the flowers precede the leaves, that the flower-clusters upon one set of trees differ in appearance from those upon another set of trees, and that all the trees are visited by multitudes of busy insects, let an abundant supply of both sorts of flowers be procured and taken to the class-room. Let the teacher then distribute the staminate flowers, and proceed with the observations upon them. Every pupil should have before him a blank schedule, in which he will set down the result of his observations, and it will be well for the teacher to have a large schedule, visible to the class, marked off upon the blackboard. Assuming that the pupils have been made acquainted with the common terms employed in the forms, let them all be required to examine the calyx, and to set down in the proper place the number of sepals. Then ascertain what has been thus set down. If all agree in their observations, the result may be accepted and recorded in the schedule on the blackboard. If there are variations, these must be looked into and noted, if correct. Then comes the question—"Polysepalous or Gamosepalous?"—the result to be checked as before. Then—"Superior or Inferior?"—to be dealt with in like manner. To fill the last column, headed "Remarks," it will not be amiss to leave the pupils entirely to their own judgment as to what they may think worth recording. When the notes have been made, the teacher may select from them such as are most worthy, and enter these in his blackboard schedule. The corolla will next be looked for and a record made. The word "Wanting" will doubtless be written down by every one, and may then be also written on the blackboard. Then the stamens come under notice. Each will set down the number he finds, and in this case it is hardly likely that all the results will agree. Some will find five, others six, others seven. When all the results have been ascertained, the teacher should enter in his form the lowest and highest numbers, thus: 5-7, as expressing the collective result, and he should improve the opportunity here presented to caution his pupils not to

infer too much from the examination of a single specimen, as variations similar to that now under notice are not uncommon. The cohesion and adhesion of the stamens will next be observed, and the "Remarks" column filled and checked as before. Pistil "Wanting" will be the next entry, and will complete the examination of the staminate blossom. The fertile flowers will then be distributed and the work carried on in the same manner, the pupils being led to find out for themselves the difference between the two kinds of flowers, and no observation on their part being considered altogether unworthy of notice, even though relatively unimportant. The significance of the invasion of the flowers by insects can now be made clear, and the pupils should be advised to observe the trees from time to time afterwards, in order to see what progress the fruit is making, to note the development of the wings, the lengthening of pedicels, and finally the sprouting of the seeds and the production of a strong new plant, all in one season. Other points, such as the shape of the leaves, comparison with other species of maple, etc., etc., may be introduced at the discretion of the teacher, but care should be taken to avoid vagueness and confusion in offering for the consideration of the pupils more than they can readily grasp, and the *relative* importance of points of structure should be distinctly brought out. For this reason a form of schedule, which will present the various features in their proper perspective and avoid giving the impression that all observations are of equal importance, is the best. It is, in the writer's judgment, a great mistake to dwell at first with any degree of minuteness upon the morphology of the various organs—to attach much importance, for instance, to the minute description of leaves. What is wanted is to get a clear apprehension of the leading characteristics of the great groups of plants, and the main facts of plant life, and anything which tends to cloud the perception of these things must be a hindrance to true progress. After typical floral forms have been examined, and some knowledge has been gained of the more comprehensive groups, then it will be proper to proceed with the study of those finer distinctions upon which depends the separation of genera and of species, and which are essential to know in order to use intelligently the classified list of the common plants of the country.

Winter Work.—As already suggested, the lessons in the fall should be as frequent as circumstances will allow, so as to complete the examination of as many typical flowers as possible. Meanwhile preparations should be going on for the winter lessons. Fruits, seeds, leaves, bulbs, tubers, cones, etc., etc., should be collected in as great variety as possible. A supply of ferns should also be laid in, neatly pressed and mounted, as these plants may be studied nearly as well in winter as in summer. Elementary microscopic work can also be just as well done in winter. Every school should now have a good compound microscope, and the teacher who can skillfully cut a few hand sections has at his command an inexhaustible source of interest and delight to his class. In all this winter work, and indeed in all botanical work, a good deal of attention should be given to *drawing*. It forms a very useful exercise, for example, to dictate or write on the blackboard, a botanical description of a leaf, and then require the class to draw the leaf so described. So, also, if a section is viewed through the microscope, a drawing of what has been observed should in all cases be demanded, as the most satisfactory way of ascertaining whether the observer has carried away the right impression; whether he has, in short, seen what he was desired to see. It will often happen, too, in the examination of minute flowers, that it becomes necessary to dissect out and exhibit separately special portions of the flower, say, for example, the pollen-masses of the milkweed, or a single stamen of the pine. The teacher should, in such a case, perform the necessary dissection; and having fixed the portion properly under the lens, pass it round for the inspection of the pupils. They may then be required to make a drawing of the object, and having thus apprehended what is necessary, may be asked to try to repeat the dissecting process for themselves.

The study of the structure and germination of seeds is another part of the work which can be very well done in winter, and many interesting and valuable lessons may be given upon these points. Seeds of different sorts should be placed upon wet flannel or blotting-paper and allowed to germinate. The

whole process may then be observed in the most convenient way, dissections and comparisons being readily made at various stages.

Spring Work.—If the programme thus lightly sketched be fairly carried out, the young botanist should be very well prepared for field work in the spring. He will now put to a practical use the information he has been acquiring about the parts of plants and their modifications, and will proceed to identify and classify the flowering plants which come in his way according to the characters which he finds them to exhibit. As soon as practicable the pupils should be required to collect and bring to the class-room any wild plants whatever which they may find in flower. If their specimens are enclosed in a suitable tin box, with a light sprinkling of water, they will remain in excellent condition for several days. It is now of minor consequence whether all the members of the class are engaged upon the same plant or not; but whether they are at work upon the same or different plants, the schedules must in all cases be conscientiously filled up before they attempt to determine the name and place of the specimen. Perhaps, for a time, until all become familiar with the use of the "flora," it would be better to work upon one plant at a time. If this plan be followed, the points of structure should be observed, recorded, and checked as already described for the earlier lessons, and when the characters of the plant have thus been definitely settled, recourse must be had to the "key" which is prefixed to the flora. Full instructions are given in the book itself for the use of this "key," so that they need not be repeated here. All the teacher has to do is to accompany the class through the various questions which have to be answered, putting them, if preferred, one by one, and receiving the answers of the class in any way he may prefer, the answers in every case, of course, to be obtained from the completed schedule. If the true name of the plant is at length arrived at, this will be the best evidence that the work of observation has been accurately performed. Two or three lessons carried out in this manner will give the pupils confidence, and familiarize them with the use of the flora, after which they may be allowed to examine and determine almost any flowering plant they may meet with. The teacher will find it useful at this stage to begin a register of the practical work done by his pupils. If prizes are given, the awarding of them may be made to depend largely upon the showing of this register. Then, if there is time, the mode of *preserving and mounting specimens* for the herbarium might be explained. Apart from its botanical importance, this work has an educational value in itself, demanding, as it does, the greatest neatness and care to ensure the most successful results. Full instructions will be found at the end of the glossary.

Excursions.—The writer cannot do better than reproduce here a short account of a botanical field day, written by him for the *Educational Monthly* some time ago, in order to illustrate how such a day may be spent :—

A BOTANICAL FIELD DAY.

It is a bright Saturday morning towards the end of June—a morning to which a score of boys and girls have for some time been looking forward with a good deal of pleasant anticipation. They are juvenile botanists, members of a class formed some months ago, and having now, by the study of selected specimens, acquired some little knowledge of the structure of plants, they are, on this particular morning, to meet for a ramble; to gather such flowers as come in their way; and then to re-assemble and compare notes, and also to determine the names of such plants as they do not already know.

The rendezvous selected is a particularly good one for botanical purposes, commanding, as it does, a variety of situations. It is an upland from which, by a gentle slope to the northward, you may descend to the reedy margin of a small lake, concealed by trees until you are close upon it. East of this lake stretches a beaver meadow of many acres, fringed and dotted with larches, and too moist to traverse in

comfort at most seasons of the year, but, in this warm and leafy month of June, solid enough under foot to dispel uncomfortable fears of false steps. If, instead of descending, you skirt along the brow of the hill, to the westward you come upon open meadows, with here and there a low copse or thicket; while to the eastward are noble woods of maple and beech, succeeded farther on by pines, as the character of the soil changes. To the southward are cultivated fields and market gardens, and in the distance the glinting of the sun on a couple of church spires marks the direction of the neighboring town.

Ten o'clock is the hour of meeting, and on this occasion an exemplary punctuality is observed by everybody. As it is intended to make a day of it, lunch baskets have not been forgotten. These are left for safekeeping at a cottage close by, and then, after a brief rest in the shade of a friendly beech, the party is divided, for the day's work, into small groups, and an area roughly marked out for each. The lower grounds and the lake region, as being somewhat difficult of access, are assigned to the sturdier boys, whilst the hillside and the exploration of the woods and fields above are divided among the remainder.

It is agreed that the work of collection shall be limited to two hours, and accordingly, as the distant boom of the noon bell comes over the fields, our botanists begin to straggle in again. It is nearly one o'clock, however, before the last detachment arrives. This consists of the boys who have made their way to the eastern end of the lake and the beaver-meadow. Their appearance is hailed with a shout of admiration, for of all the collections of flowers, theirs is certainly the most imposing. They must, indeed, have hit upon a veritable botanic garden, for each of them carries a huge bouquet, made up of a profusion of Lady's Slippers and other Orchids, together with Lilies, Pitcher Plants, and beautiful pink Pyrolas. These boys are flushed with the excitement of their walk and their success; and though the condition of their lower extremities would seem to indicate that they are not altogether unacquainted with bogs, they make no reference thereto, but dwell with enthusiasm, and some degree of extravagance perhaps, on the beauties of the scene they have just left. But the others, though their collection will not vie in brilliancy with the products of the beaver-meadow, have, nevertheless, in nearly every case, something of more than ordinary interest to show. The explorers of the lake margin were fortunate enough to find a punt, by means of which a number of aquatic plants, Yellow Pond Lilies, Utricularias, the pretty white Water-Crowfoot, and the Water-Shield, were brought within their reach; and on the cool northern hill-side, trailing over the base of moss-covered stumps, specimens of the Twin-Flower—a special favorite of the great Linnæus, and named *Linnæa borealis* in his honor—were obtained, as well as Violets of various species, Woodbines, Mitchellas, etc. The open fields and fence-rows yielded St. John's-worts, Elder, Gnaphaliums of several species, a handsome Rudbeckia—the purple Cone-flower—and of course the ubiquitous Dandelion, and Mayweed, and Mullein.

But just now there are cravings which are not intellectual, cravings too urgent to be disregarded. The interest in botany is, at this moment, decidedly of a secondary nature, and when the lunch baskets are sent for, and their contents exposed to view, the gravest doubts of their sufficiency are entertained and freely expressed. The fullest kind of justice is done them, and in the course of a few minutes no vestige whatsoever remains—nothing even suggestive of them, save the shrunken wrappers, upon which some eyes are now turned with an expression almost approaching to gloom. It is suggested, and the suggestion meets with no opposition, that whatever may be the merits of botanical pursuits from an intellectual point of view, they have recommendations of a physical nature, not wholly unworthy of consideration; and it begins to dawn upon these youthful scientists, though as yet they have no clear conception of the ideal *mens sana in corpore sano*, that Botany has this decided advantage over all other school studies, that, to pursue it with efficiency, exercise of body must accompany exercise of mind. They can also comprehend that the botanical laboratory is as free as air to everyone who wishes to make use of it; that everywhere around them the lavish productions of nature are only waiting to be asked, to unfold their beauties; and that anyone who holds converse with the silent yet eloquent creations of the floral world, must become imbued with more or less of the feeling which inspired the tenderest of American poets, when he sang of the flowers as

> "Teaching us by most persuasive reasons
> How akin they are to human things."

But the afternoon is advancing, and important work still remains to be done. It is not enough to admire color and form; we must look a little deeper, and analyze the structure of our flowers with as much

minuteness as may be suited to the capacity of the present students. In other words, we propose to turn our ramble to practical account in the way of an object-lesson, and to test the observing faculties by trying to assign to each plant its proper place in a botanical classification. A good many of the plants are recognized, without much difficulty, as being near relatives of species already examined in the class-room; the Lady's Slipper, for instance, is at once pronounced to be an Orchid; the Pitcher-Plant is immediately identified by its leaves, the Water-Crowfoot is only a white Buttercup; the few Composites in bloom at this season are referred at once to the proper family; and so with a number of others. But there are some which cannot be disposed of in this off-hand manner, and for these our "Flora" must be consulted. For convenience, it is arranged that one person shall read aloud from the manual, while the others, with specimens in hand, listen to the descriptions, and assent or dissent, as these correspond to the characters exhibited by the plant under examination, or the reverse, until finally its true place and name are revealed. These having been duly noted down, along with the date of collection and the locality, other specimens are taken up in the same way; and though it is found impossible to overtake all the plants that have been gathered, yet considerable headway is made, and even the dullest (for our class, not being an ideal one, contains dull as well as clever pupils) feel a certain degree of confidence in their ability to do a little botanical work on their own account.

The work of determination is not prolonged to weariness, and soon after three o'clock preparations are made to return home. The fatigue of the morning's walk has completely disappeared, and the youthful mind, released from the strain to which it has been subjected, unbends, and with that singular fertility of resource which causes the average juvenile to be at once the envy and the terror of his elders, immediately advances a host of topics for discussion, quite foreign to the object of the day's proceedings. Botany is for the present laid aside, and it ceases to be a matter of any consequence whatever, whether stamens are hypogynous or otherwise, or what may be the relation of the calyx to the ovary. With pleasant conversation the homeward way is beguiled, and as we separate, a hope, which is believed to be genuine, is expressed that ere long we may meet again for another Field Day.

PRACTICAL EXERCISES.

1.—Examine and record, with drawings, the modes of vernation in six different plants.

2.—Compare the leaves of Red Maple, Silver Maple, and Sugar Maple, making drawings.

3.—Compare the leaf-clusters of the White Pine, Red Pine, and Tamarack.

4.—Determine the phyllotaxis in six different plants.

5.—Make a cross-section of a cluster of the leaves of the Blue Flag, near the base. Make a drawing of the section.

6.—Examine buds of the following, with special reference to protective coverings: Lilac, Spruce, Horse-chestnut, Beech, Poplar. Make notes of what you observe. Where bud-scales are present examine their inside surfaces.

7.—Compare the climbing apparatus of the Pea with that of the Bean.

8.—Compare as to mode of growth and ramification the stems of the Apple-tree and the Pine.

9.—Make vertical sections of the eye of a Potato, an Indian Turnip, and an Onion, and make drawings of the sections.

10.—Make vertical and cross-sections of three different buds. Draw the sections.

11.—Examine the prickles of a Bramble and of a Galium. Are they hooked downwards or upwards? Of what service are they to the plants? Give reasons for your opinion.

12.—Examine the ends of shoots of the Lilac towards the close of summer. Note the replacement of the terminal bud by two lateral ones. Examine these again late in the fall.

13.—Examine tendrils of the Grape-vine and Virginia Creeper, noting any difference in their mode of action.

14.—Examine the twining stems of the Hop and the Morning Glory, noting differences.

15.—Detach bulblets from the axils of the leaves of the Tiger Lily, and plant them. Record results.

16.—Cut with a knife into the stems of an exogen and a woody endogen (Bamboo, for example). Note and account for any difference in the difficulty of cutting through the outer surface.

17.—Examine and record, with drawings, the modes of æstivation in six different flowers.

18.—Draw floral diagrams of six different flowers, and write out the formulas.

19.—Compare the *head* of the Thistle with that of the Red Clover.

20.—Detach with the point of a pencil the pollen-masses in any orchid flower, thus imitating the action of an insect. Note the downward contraction of the pollen-mass shortly after its withdrawal. What purpose is served by this contraction? Extract also the pollen-masses from a flower of Milkweed.

21.—Observe whether insects visit the flowers of any of the following: Pine, Willow, Cucumber, Maple.

22.—Make and draw sections of six different ovaries.

23.—Soak a bean in water for an hour or two, and then dissect it, exhibiting all its parts.

24.—Compare the pappus of the Dandelion with the silky hairs upon the seeds of Milkweed and of Willow-herb. Note differences of origin.

25.—Bury a bean and an acorn in moist, warm sawdust, and note any difference in the phenomena of germination.

26.—Gather a few acorns and seeds of the Red Maple and lay them away for the winter. In the spring test their germinating powers.

27.—Examine scales of green pine-cones, and also of ripe ones.

28.—Study the dehiscence of the ovary in Purslane, Shepherd's Purse, Catchfly, Columbine, Mallow, Morning Glory.

29.—Dissect out the embryos from six albuminous seeds.

30.—Observe through a good microscope, and make drawings of:—

(*a*) Six different pollen-grains.
(*b*) A thin slice of Elder pith.
(*c*) A shred torn from the under surface of a leaf.
(*d*) A similar shred from the upper surface.
(*e*) A cross-section of a bit of Lilac leaf with a vein in it.
(*f*) A plant-hair.
(*g*) A vertical section through the tip of a rootlet.
(*h*) A thin slice of Potato.
(*i*) The bloom on a Cabbage-leaf.

31.—Make cross-sections of the Bamboo and a branch or small stem of any of our native woods. Examine with a lens, and write notes on the different appearances presented.

32.—Examine the bark of a young tree and also of an old one of the same kind. Note any differences and account for them.

33.—Examine a bit of the under side of a leaf of Sweet-brier under a good microscope. Give your opinion of the source of its odour.

34.—Examine the sticky stem of the Catchfly. What causes the stickiness? What is its probable use?

35.—Examine the scurfy under surface of a leaf of the common Shepherdia. View a small portion under a good microscope and write notes on what you observe.

36.—Scrape the surface of a slice of Potato with a knife, mount the scraping, and examine with a good microscope. Add a drop or two of solution of iodine; examine again, and describe and explain the result.

37.—Try similar experiments with a Turnip, a Carrot, an Apple, a softened Pea, and write notes on the results.

38.—Study the germination of a Pea, a Windsor Bean, and a grain of Indian Corn. Write notes upon any phenomena observed. Try the effect of different temperatures on the rapidity of germination.

39.—Observe and write notes upon the different aspects presented by plants when grown in the shade and when exposed to full sunlight.

40.—Immerse a few green leaves in a bottle full of water. Invert upon a shallow dish of water without spilling. Expose the whole to strong sunlight, and examine after two or three hours. Describe and explain anything you observe.

41.—Repeat the last experiment, placing the apparatus in a dark closet. Note results.

42.—Fill about one-third of a large wide-mouthed bottle with well-soaked Peas. After three or four hours carefully remove the stopper and lower into the bottle a lighted match or taper. Note and explain results.

43.—Grow a hyacinth or a crocus in a perfectly dark cellar. Note the effect upon the colour of the leaves, and also upon that of the flowers.

44.—A plant growing in a window bends towards the light. What inference would you draw as to the effect of light upon the rate of growth?

45.—Procure and examine the structure of the little bladders found on the immersed leaves of the common Bladderwort. Note the action of the trap-door leading into the bladder. Examine also the contents, and make notes of your observations.

46.—Examine the structure and contents of the leaves of the Pitcher-plant. Make drawings and notes.

BOTANICAL WORK

PRESCRIBED BY THE EDUCATION DEPARTMENT FOR ONTARIO.

PRIMARY EXAMINATION.

The practical study of representatives of the following natural orders of flowering plants: Ranunculaceæ, Cruciferæ, Malvaceæ, Leguminosæ, Rosaceæ, Sapindaceæ, Umbelliferæ, Compositæ, Labiatæ, Cupuliferæ, Araceæ, Liliaceæ, Iridaceæ, Coniferæ, and Gramineæ (types contained in text book).

Drawing and description of plants and their classification.

Comparison of different organs, morphology of root, stem, leaves and hair, parts of the flower, germination, reproduction of flowering plants, pollination, fertilization, and the nature of fruits and seeds.

JUNIOR LEAVING EXAMINATION.

The practical study of representatives of the flowering plants of the locality, and representatives of the chief subdivisions of cryptogams, such as a fern, a lycopod, a horsetail, a liverwort, a moss, a lichen, a mushroom, and a chara.

Drawing and description of parts of plants, and classification.

Comparison of different organs, morphology of root, stem, leaves, and hair, parts of the flower, reproduction of flowering plants, pollination, fertilization, and the nature of fruits and seeds.

SENIOR LEAVING EXAMINATION.

The practical study of representatives of the flowering plants of the locality, and representatives of the chief subdivisions of cryptogams, such as a fern, a lycopod, a horsetail, a liverwort, a moss, a lichen, a mushroom, and a chara.

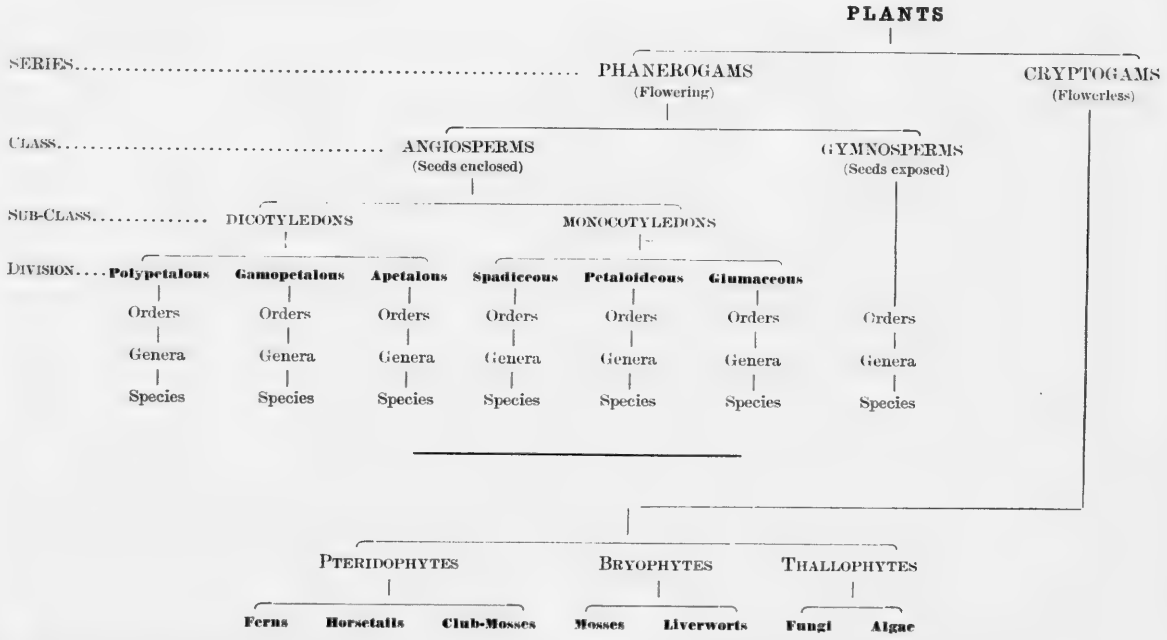
An elementary knowledge of the microscopic structure of the Bean and the Maize.

Drawing and description of parts of plants, and classification.

Comparison of different organs, morphology of root, stem, leaves and hair, parts of the flower, reproduction of flowering plants, pollination, fertilization, and the nature of fruits and seeds.

OUTLINE OF CLASSIFICATION.

NOTE.—It will be observed that the arrangement of the groups in this outline is slightly different from that in the key. A comparison of the two arrangements will be useful. The present one is that which is now generally preferred.



Pteridophytes
Bryophytes
Thallophytes
Ferns
Horsetails
Club-Mosses
Mosses
Liverworts
Fungi
Algae

GLOSSARY.

GLOSSARY OF

BOTANICAL TERMS

USED IN PLANT DESCRIPTION.

THE ROOT.

Origin.

PRIMARY: when originating directly from the lower end of the radicle of the embryo (Fig. 1). Such a root is usually (but not always) single, and may send out lateral fibres as it grows; such fibres or branches are included in the primary root.

Annuals and biennials, and many trees, have, as a rule, only primary roots.

SECONDARY: when originating from any other part of the plant than the end of the radicle, as from the sides of stems (Fig. 2), from tubers, rootstocks, bulbs, cuttings, etc.

Perennial herbs, creeping plants, and most shrubs, produce such roots abundantly.

Form.

TAP: having a main central axis, distinctly larger than any of the branches (Fig. 3).

FIBROUS: made up of many similar parts without a distinct central axis (Fig. 4).

A tap-root is

(a) *Conical*, when it gradually tapers from a broad top (Fig. 5).

(b) *Spindle-shaped* or *fusiform*, when thickest in the middle (Fig. 6).

(c) *Turnip-shaped* or *napiform*, when nearly globular with an abruptly tapering base (Fig. 7).

Fibrous roots are

(a) *Of coarse threads*, as in Buttercup.

(b) *Of fine threads*, as in any common grass.

(c) *Fascicled* or *clustered* or *tuberous*, when each of the fibres has become a fleshy mass, as in Peony (Fig. 8).

(In description the Variety may follow the Form on the same line; for example, FORM: *Tap, conical.*)

Colour.

In many plants the colour of the root is characteristic, and should always be given in the description.

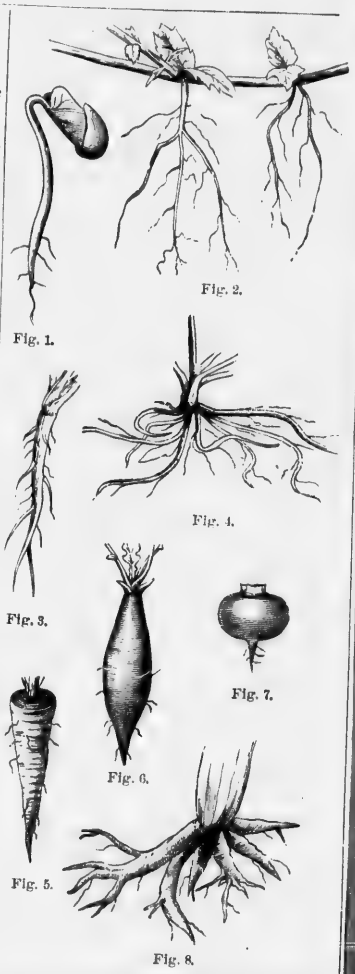


Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.

Position.

SUBTERRANEAN: when, as in most cases, the root is underground.

AÉRIAL: when the roots spring from the sides of the stem above ground, as in Poison Ivy, which uses roots for climbing; and in Indian Corn.

AQUATIC: when suspended in water, as in Duckweed.

Duration.

ANNUAL: lasting one season only.

BIENNIAL: lasting two seasons.

PERENNIAL: lasting year after year.

Fig. 9.

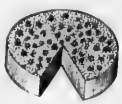


Fig. 10.

THE STEM.

Class.

EXOGENOUS (or DICOTYLEDONOUS): with the wood in annual layers or rings (Fig. 9).

Note that plants with exogenous stems have also the following characters:

(a) The embryo of the seed has more than one (usually two) cotyledons.

(b) The leaves are net-veined.

(c) The parts of the flower are usually *not* in threes or sixes, but commonly in fours or fives.

(d) They have a true bark.

Fig. 11.

ENDOGENOUS (or MONOCOTYLEDONOUS): with the wood not in rings but scattered through the stem (Fig. 10).

Plants with endogenous stems have also the following characters:

(a) The embryo has but one cotyledon.

(b) The leaves are nearly always straight-veined.

(c) The parts of the flower are never in fives, but almost invariably in threes or sixes.

(d) They have no true bark.

Fig. 12.

Attitude.

ERECT: growing directly upwards.

DECLINED: bending over towards the ground.

PROSTRATE, or PROCUMBENT, or TRAILING: lying flat along the ground.

CREEPING: lying flat, and striking root at intervals (Fig. 11).

DIFFUSE: spreading in all directions.

ASCENDING: growing upwards in a slanting direction.

CLIMBING: when the stem raises itself by means of tendrils (Fig. 12) or leaf-stalks, or hooked prickles, which lay hold of neighbouring plants or other objects.

TWINING: when the stem itself coils round the support (Fig. 13).

Fig. 13.

Texture.

HERBACEOUS: with little or no wood, and dying down to the ground each year.

WOODY: as in shrubs and trees.

SUFFRUTICOSE: woody at the base, but herbaceous at the top.

Position.

AËRIAL: growing above ground.

SUBTERRANEAN: growing under ground.

Of subterranean stems there are the following varieties:

(a) *Rhizome*, or *Rootstock*: a horizontal, more or less fleshy, perennial underground stem, which produces each season a new bud at its extremity, from which the annual overground stem is developed, as in Trillium, Bloodroot, and most of our early-flowering herbs (Fig. 14).

(b) *Tuber*: the thickened end of a rhizome, as the Potato and Jerusalem Artichoke (Fig. 15).

(c) *Bulb*: a globular mass, usually made up of fleshy leaves attached to a short flat stem, as the Lily (Fig. 16) and Onion.

(d) *Corm*: a bulb having the stem part very large compared with the bud or leaf part, as in Indian-Turnip (Fig. 17).

A plant is described as *acaulescent*, or stemless, when the stem is very short and the leaves spring in a cluster from the surface of the ground, as in Dandelion and Hepatica.

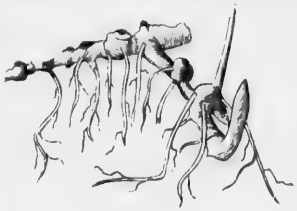


Fig. 14.

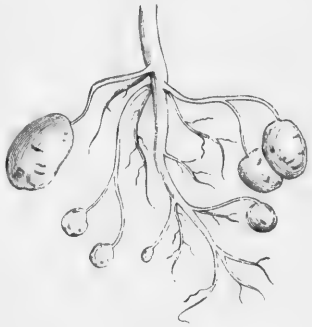


Fig. 15.

Fig. 16.

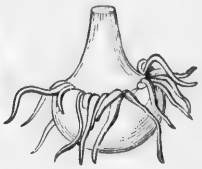


Fig. 17.

Shape.

TERETE: cylindrical (Fig. 18).

COMPRESSED: somewhat flattened (Fig. 19).

TRIANGULAR: Fig. 20

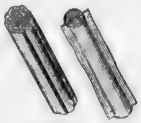
SQUARE: Fig. 21.

GROOVED: Fig. 22.

WINGED: Fig. 23.

STRIATE: with lines running lengthwise.

Figs. 18. 19. 20. 21.



Figs. 22. 23.

Juice.

In some cases the colour or taste of the juice is characteristic, and should be mentioned: Bloodroot has a red juice, Milkweed a milky juice, Celandine a yellow juice, Buttercup a colourless *bitter* juice, Sorrel a colourless *sour* juice, etc.

Branching.

The stem is

SIMPLE: when branches are entirely wanting, as in Mullein.

EXCURRENT: when the main stem can be traced through to the top, as in Fir and Pine.

DELIQUESCENT: when the main stem is soon lost in the branches, as in most shrubs.

WITH RUNNERS: when there are slender branches from the base of the stem which take root at the end, as in Strawberry, etc. (Fig. 11).

WITH STOLONS: when branches bend over so as to reach the ground and take root (Fig. 11).

WITH SUCKERS: when an underground branch sends up a stem at a distance from the parent plant, as in Mint, etc. (Fig. 11).

TENDRILS are sometimes branch-forms, as those of the Grape (Fig. 12).

SPINES, as in Hawthorn, are also branch-forms, stunted and pointed (Fig. 24).

THE LEAF.

Parts.

BLADE: the broad part.

PETIOLE: the leaf-stalk.

STIPULES: two small usually leaf-like pieces, one on each side of the petiole where it joins the stem of the plant (Fig. 25); but sometimes the stipules are in the form of spines, as in Locust, and sometimes they form a tube around the stem, as in Smartweed (Fig. 27).

SHEATH: the tubular petiole which surrounds the stem in many Endogens (Fig. 26).

LIGULE: the thin semi-transparent appendage growing at the top of the sheath in most grasses. It appears to be an upward extension of the lining of the sheath (Fig. 26).

Position.

RADICAL: when arising from the stem at or below the surface of the ground.

CAULINE: all the leaves higher up the stem.

In plants like Dandelion and Hepatica *all* the leaves are radical. In Buttercup and Shepherd's Purse there are both kinds (Fig. 28).

Arrangement.

ALTERNATE: when only one leaf springs from a node, or joint of the stem (Fig. 29).

OPPOSITE: when two leaves spring from each node on opposite sides of the stem; and opposite leaves are *decussate* when each pair is at right angles to the next pair (Fig. 30).

WHORLED, or VERTICILLATE: when three or more leaves spring from a node (Fig. 31).

FASCICULATE: when there are several leaves in a bundle, as in Pine, Larch, etc. (Fig. 32).

Fig. 24.

Figs. 27, 26, 25.

Fig. 28.

Fig. 31.

29.

30.

Fig. 32.

Division.

SIMPLE: when the blade is in one piece, however deeply it may be cut.

COMPOUND: when the blade is in two or more distinct pieces, which are then known as *leaflets*.

A compound leaf is

(a) *Pinnate*: when the leaflets are arranged on each side of a central or mid rib; and such a pinnate leaf will be *odd-pinnate* if there is an odd leaflet at the end (Fig. 33); *abruptly-pinnate* if there is not a terminal leaflet (Fig. 34); and *pinnate with a tendril* if the mid-rib ends in a tendril, as in Pea, etc. (Fig. 35).

Again: the leaf is *twice-pinnate* if the primary divisions are themselves pinnate (Fig. 36); *thrice-pinnate* if the subdivision is carried through another stage; and *decompound* if still more divided.

It is *interruptedly-pinnate* if, as in Tomato, there are small leaflets interspersed among the larger ones (Fig. 37).

(b) *Palmate*: if the leaflets are spread out from the end of the petiole, like fingers (Fig. 38).

A compound leaf is further described by mentioning the number and form of the leaflets. (An example of the complete description of a compound leaf is given at the beginning of the leaf-schedules later on).

Venation.

STRAIGHT-VEINED: when the veins run nearly parallel, either from end to end of the leaf, as in grasses (Fig. 39), or from a central rib to the margin, as in Calla (Fig. 40).

NET-VEINED: when the veins run in all directions, forming a net-work. Such a leaf is

(a) *pinnately-net-veined*: when there a distinct central rib with the smaller veins branching from it on each side (Fig. 41); and

(b) *palmately-net-veined*: when there are several chief ribs radiating from the end of the petiole (Fig. 42).

Outline.

1. Of leaves nearly alike at both ends.

FILIFORM: thread-like, as in Asparagus.

ACICULAR: needle-shaped, as in Pine (Fig. 43).

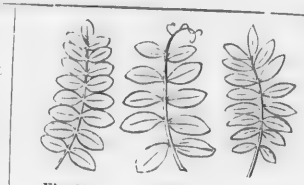


Fig. 33. Fig. 35. Fig. 34.

Fig. 36.

Fig. 37.

Fig. 39. Fig. 40.

Fig. 38.

Fig. 43.

Fig. 41.

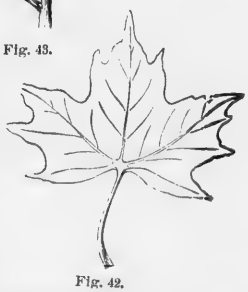


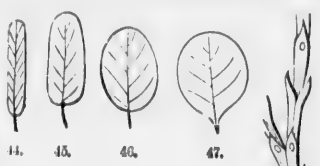
Fig. 42.

LINEAR: narrow compared with the length (Fig. 44).

OBLONG: not more than three times as long as broad, and with sides inclined to be straight (Fig. 45).

OVAL, or ELLIPTICAL: not more than twice as long as broad (Fig. 46).

ORBICULAR: round, or nearly so (Fig. 47).



44. 45. 46. 47.

Fig. 48.

2. Of leaves broadest below the middle.

SUBULATE: awl-shaped (Fig. 48).

LANCEOLATE: as in Fig. 49.

OVATE: as in Fig. 50.

DELTOID: about as broad as long, and rather triangular (Fig. 51).

Fig. 49. Fig. 50. Fig. 51.

3. Of leaves broadest above the middle.

OBLANCEOLATE: the reverse of lanceolate (Fig. 52).

SPATHULATE: like the last, but more rounded at the top (Fig. 53).

OBOVATE: the reverse of ovate (Fig. 54).

WEDGE-SHAPED, or CUNEATE: like the last, but with the end more flattened and the margins nearly straight (Fig. 55).

In describing outlines, it will often be necessary to combine terms, as for example: *linear-oblong, linear-lanceolate, oblong-ovate*, etc. as the case may require.

Figs. 52. 53. 54, 55.

Margin.

ENTIRE: not indented in any way (Fig. 56).

SERRATE: with sharp teeth pointing forward like the teeth of a saw (Fig. 57).

SERRULATE: very finely serrate (Fig. 58).

DENTATE: with teeth pointing outward (Fig. 59).

CRENATE: with teeth rounded at the point (Fig. 60).

A margin may also be *doubly-serrate* (Fig. 61), *doubly-dentate*, or *doubly-crenate* (Fig. 62), when the larger teeth are themselves serrate, or dentate, or crenate.

SINUATE: deeply wavy (Fig. 63).

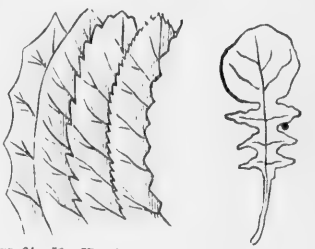
CILIATE: with a fringe of hairs.

REVOLUTE: with the edge turned back.

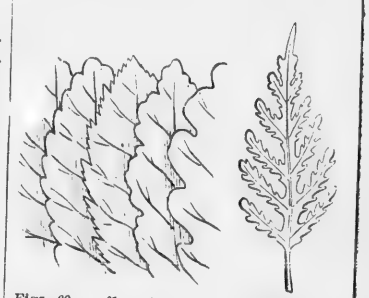
REPAND: like the edge of an expanded umbrella (Fig. 64).

PINNATIFID: when the edge of a pinnately-veined leaf is very deeply lobed (Fig. 65).

BI-PINNATIFID: when the first lobes are themselves pinnatifid (Fig. 66).



Figs. 64. 56. 57. 58. 59. Fig. 65.



Figs. 60. 61. 62. 63. Fig. 66.

PALMATIFID: when the edge of a palmately-veined leaf is very deeply lobed (Fig. 67).

PECTINATE: when the edge somewhat resembles the teeth of a comb.

LYRATE: pinnatifid, with a very large lobe at the end (Fig. 65).

RUNCINATE: pinnatifid, with the lobes pointing backwards, as in Dandelion (Fig. 68).

PEDATE: palmatifid, with the lobes at the base two-cleft (Fig. 69).

MULTIFID: cut into many fine segments or lobes, as in Milfoil.

Apex.

ACUMINATE: running out to a long slender point (Fig. 70).

ACUTE: making an acute angle (Fig. 71).

OBTUSE: making an obtuse angle; blunt (Fig. 72).

TRUNCATE: as if the end were cut off square (Fig. 73).

RETUSE: with the end slightly indented (Fig. 74).

EMARGINATE: with a distinct notch (Fig. 75).

OBCORDATE: rather deeply notched (Fig. 76).

CUSPIDATE: with a short but distinctly tapering point (Fig. 77).

MUCRONATE: with a fine sharp point projecting beyond the end of the mid-rib (Fig. 78).

ARISTATE: tipped with a bristle.

Base.

ACUTE: making an acute angle (Fig. 79).

OBTUSE: making an obtuse angle; blunt (Fig. 46).

TAPERING: with a long and slender base (Fig. 80).

CORDATE: rounded and notched (Fig. 67).

AURICULATE: with two small rounded lobes (Fig. 81).

SAGITTATE: with sharp lobes pointing downwards (Fig. 83).

HASTATE: with sharp lobes pointing outwards (Fig. 84).

PELTATE: when the petiole is attached, not to the edge, but to the under surface (Fig. 85).

RENIFORM: with very large rounded lobes (Fig. 86).

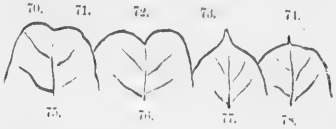
CLASPING: when the leaf is sessile, and the lobes are close against the stem on each side (Fig. 82).

Fig. 67.

Fig. 68.

Fig. 69.

70. 71. 72. 73. 74.



75. 76. 77. 78.

79. 80. 81.

Fig. 82.

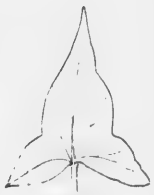


Fig. 84.

Fig. 85.

Fig. 86.

PERFOLIATE: when the lobes of a sessile leaf grow together at the back of the stem, so that the stem seems to pass through the leaf (Fig. 87).

CONNATE, or CONNATE-PERFOLIATE: when two opposite sessile leaves grow together by their bases (Fig. 88).

DECURRENT: when the lobes of a sessile leaf grow down the sides of the stem (Fig. 89).

Fig. 87.

Fig. 88.

Fig. 89.

Surface.

(The student should use his lens in determining the character of the surface of either stem or leaf.)

SMOOTH, or GLABROUS: entirely without hairs.

GLAUCOUS: covered with a bloom which may be rubbed off with the fingers, as in Cabbage.

PUNCTATE: showing transparent dots when held up to the light, as in St. John's Wort.

SCABROUS: rough, but without hairs.

PUBESCENT: covered with fine soft short hairs.

VILLOUS: with long soft hairs.

TOMENTOSE: with matted hairs.

SERICEOUS: with silky hairs.

HOARY: with white down.

HISPID: with stiff hairs.

SPINOUS: with scattered spines.

RUGOSE: wrinkled.

CILIATE: with hairs on the *edge*.

Colour.

The colour of the leaf must be described by an appropriate term, and if, as is often the case, the two surfaces differ in colour, this fact must be noted.

Texture.

Leaves differ very much in texture. Some are very thin and soft, others almost leathery, while others again are very thick and fleshy. In describing a leaf, judgment must be exercised in selecting a suitable term.

Duration.

FUGACIOUS, or CADUCOUS: falling off early in summer.

DECIDUOUS: falling off in autumn, as in most trees and shrubs.

PERSISTENT, or EVERGREEN: remaining at least a year on the plant.

Vernation, or mode of folding in the bud.

CONDUPLICATE: doubled lengthwise. Shown in cross-section in Fig. 90.

PLICATE: folded like a fan, as in Mallow (Fig. 91).

CONVOLUTE: rolled from one edge to the other (Fig. 92).

Fig. 90.

Fig. 91.

Fig. 92.

INVOLUTE: rolled inward from both edges (Fig. 93).
REVOLUTE: rolled backward from both edges (Fig. 94).
CIRCINATE: coiled from the apex, as in Ferns (Fig. 95).
EQUITANT: each leaf doubled lengthwise and astride of the next leaf within, as in Iris (Fig. 96).

Fig. 93.

Fig. 94.

Fig. 95.

INFLORESCENCE.

Arrangement of the Flowers or Flower-clusters on the stem.

Mode.

TERMINAL: when the separate flowers are on the ends of stems or branches.

Terminal Inflorescence is also known as DETERMINATE, or DEFINITE, or CYMOSE, or CENTRIFUGAL, and it is

(a) *Solitary:* when a single flower terminates the stem, as in Tulip and Hepatica. In other words the flowers do not form a cluster (Fig. 97).

(b) *A Cyme:* when the flowers are in a cluster of which the central flower (on the end of the main stem) is the earliest (Fig. 98), as in Chickweed and Sweet-William. In Chickweed the cyme is *loose*, and in Sweet-William it is *dense*.

(Special cases of Cymes arising from the axils of leaves are referred to below under the head of Mixed Inflorescence.)

AXILLARY: when the separate flowers spring from the axils of leaves or bracts.

Axillary Inflorescence is also known as LATERAL or INDETERMINATE, or INDEFINITE, or RACEMOSE, or BOTRYOSE, or CENTRIPETAL; and it is

(a) *Solitary:* when the flowers are produced singly in the axils of ordinary leaves (not bracts), as in Morning-Glory, etc. The flowers do not form a cluster.

(b) *A Raceme:* when the flowers form a rather long cluster, each flower being in the axil of a bract, and having a pedicel (little stalk) of its own (Fig. 99).

(In plants of the Cress family the bracts are absent.)

(c) *A Spike:* when the separate flowers are sessile, or nearly so, along the main axis, as in Hollyhock, etc. (Fig. 100).

(d) *A Head:* when the axis of the cluster is short, and the flowers consequently rather closely packed together, as in Clover and Thistle, etc.

(e) *An Umbel:* when the pedicels of the flowers are of the same length, and arise from the same point (Fig. 101).

(f) *A Corymb:* when the pedicels arise from different points on the stem, but the flowers reach the same level above (Fig. 102).

Fig. 97.

Fig. 96.

Fig. 98.

Fig. 99.

Fig. 102.

Fig. 100.

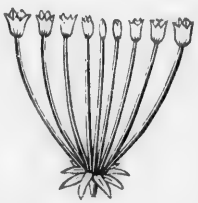


Fig. 101.

The Raceme, Umbel, and Corymb may be compound, as shown in Figs. 103 (compound Raceme) and 104 (compound Umbel).

(g) *A Catkin:* when the flowers (usually imperfect) arise from scale-like bracts along a slender axis. The Catkin is thus a special kind of spike (Fig. 105).

(h) *A Spadix:* when the flowers (often imperfect) are arranged in a spike-like cluster on a fleshy axis, as in Indian-Turnip (Figs. 106 and 107).

The Spadix is usually surrounded by a large showy bract called a spathe (Fig. 108).

MIXED: when axillary and terminal forms are combined. For example, in many Composites the inflorescence is terminal or cymose *as to the heads themselves*, while each head separately is always axillary or lateral as to the development of the florets of which it is made up. The chief varieties of mixed inflorescence are

(a) *The Thyrse:* a cluster like that of Lilac, in which the primary branches are lateral, and the secondary cymose.

(b) *Verticillaster:* a cluster like that of Catnip and Mint flowers generally, where two dense cymes form in the axils of opposite leaves, giving the appearance of a whorl.

In connection with inflorescence the following terms should be noticed:

Peduncle: the flower-stalk, or in the case of clusters the stalk supporting the whole cluster.

Pedicel: the separate stalk of each flower in a cluster.

Scape: a leafless flower-stalk rising from the ground or near it, as in Tulip and Dandelion.

Bract: a foliage-leaf, differing from the ordinary leaves of the plant in size, shape or colour, and found under the flower or flower-cluster.

Bractlet: a secondary bract, as seen on the pedicels in Fig. 103.

Involucre: a circle of bracts, such as the outer leaves of Composite flowers like Dandelion, etc. (Fig. 109).

Involucel: a secondary or minor involucre or circle of bractlets, such as is commonly found under the small clusters of a compound umbel (Fig. 104).

Fig. 103.

Fig. 104.

Fig. 105.

Figs. 106, 107.

Fig. 108.

Fig. 109.

THE FLOWER.

Parts:

Calyx: the outer set of flower-leaves, usually green or greenish, as in Buttercup (Fig. 110).

The pieces of which the calyx is made up are called *sepals*.

Corolla: the second set of flower-leaves, immediately within the calyx, and usually some other colour than green (Fig. 110).

The pieces of which the corolla is made up are called *Petals*.

These two sets taken together are known as the *Floral Envelopes*, and also as the *Perianth*, but the latter term is generally restricted to the flowers of Monocotyledons, such as Lilies, where the parts are very much alike. Some flowers of Dicotyledons, such as Marsh-Marigold (Fig. 111), have only *one* set of floral envelopes, and this is then nearly always the calyx, no matter what its colour is.

Stamens or Andrœcium: the third set of flower-leaves, appearing as thread-like stalks with thickened ends (Fig. 112). These produce the *pollen*.

Pistil or Gynœcium: the central organ of the flower which bears the seed. It may be in several pieces, as in Buttercup (Fig. 113), or in one piece as in Shepherd's Purse (Fig. 114).

These last two sets taken together are the *Essential Organs* of the flower. They alone are directly concerned in the production of seed. The floral envelopes protect the essential organs, and attract insects which help to distribute the pollen.

Receptacle: the enlarged top of the peduncle to which the parts of the flower are attached.

Note also the following points: Flowers are

(a) Perfect, if they have both stamens and pistil, whether calyx and corolla are present or not.

(b) Imperfect, if either stamens or pistil is wanting. And imperfect flowers are

(1) *Staminate*, if they bear stamens, but not pistil, as in Willow (Fig. 115).

(2) *Pistillate*, if they bear pistils, but not stamens, as in Willow (Fig. 116).

(3) *Neutral*, if both stamens and pistil are absent.

(4) *Monœcious*, when staminate and pistillate flowers are borne on the same plant, as in Cucumber and Indian Corn.

Fig. 110.

Fig. 111.

Fig. 112.

Fig. 113.

Fig. 114.

Fig. 115.

Fig. 116.

(5) *Dœcious*, when staminate and pistillate flowers are borne on different plants, as in Willow.

(c) POLYGAMOUS, when there is a mixture of perfect and imperfect flowers.

(d) COMPLETE, if all four parts, viz: calyx, corolla, stamens, and pistil, are present.

(e) INCOMPLETE, if any one or more of the four sets are wanting. Incomplete flowers are *achlamydeous* when calyx and corolla are both wanting, as in Willow.

(f) SYMMETRICAL, if the different sets consist of the same number of pieces each, or of a multiple of the same number, for example: 4 sepals, 4 petals, 8 stamens, 4 carpels.

(g) UNSYMMETRICAL, if there are not the same number of pieces (or a multiple of the same number) in each set.

(h) REGULAR: when the pieces of each set are alike in size and shape, as in Buttercup (Fig. 110).

(i) IRREGULAR: when the pieces of each set are not alike in size and shape, as in Sweet Pea, Orchid, etc. (Fig. 117).

Fig. 117.

THE CALYX.

Cohesion (union of like parts).

POLYSEPALOUS: with the sepals entirely distinct from each other, so that they can be pulled off separately, as in Buttercup (Fig. 110).

GAMOSEPALOUS: when the sepals are all united together (Fig. 118).

The following terms are applicable to the gamosepalous calyx:

(a) *The Tube*: the lower united part (Fig. 118).

(b) *The Limb*: the upper separated part (Fig. 118), made up of lobes or teeth. In many composite flowers the limb is pappose, consisting of fine bristles (Fig. 119).

(c) *The Throat*: the entrance to the calyx-tube.

Fig. 118.

Pappus.

Fig. 119.

Adhesion (union of unlike parts).

INFERIOR: when the calyx is plainly beneath the ovary and free from it, as in Buttercup, etc. (Fig. 112).

SUPERIOR: when the calyx-tube grows fast to the outside of the ovary and the limb rises above it, as in Apple, etc. (Fig. 120).

Fig. 120.

Duration.

Fugacious or Caducous: falling off as soon as the flower opens, as in Bloodroot and Poppy.

Deciduous: falling off about the same time as the corolla and stamens, as in Buttercup.

Persistent: remaining after the corolla has fallen off, as in Hollyhock and Sweet-Brier (Fig. 121).

As the sepals are only modified leaf-forms, they may be further described by means of the terms already explained for leaves, such as *lanceolate*, *pubescent*, etc.

THE COROLLA.

Cohesion.

Polypetalous: when the petals are entirely distinct from each other, as in Buttercup (Fig. 110). In such petals two parts may often be distinguished, a broad upper part, the *limb*, and a narrower lower part, the *claw* (Fig. 122).

Gamopetalous: when the petals are grown together in however slight a degree, so that the corolla may be pulled off in one piece, as in Convolvulus, etc. (Fig. 123).

The terms *tube*, *limb* and *throat* are applicable to such corollas, as well as to the gamosepalous calyx.

A gamopetalous corolla is further described by stating its *Form*. It is

(a) *Tubular*, when of nearly the same width from top to bottom (Fig. 124).

(b) *Funnel-shaped*, when the tube spreads out gradually into a wide border (Fig. 123).

(c) *Campanulate*, or bell-shaped, when the tube is short and wide, with a slightly spreading border (Fig. 125).

(d) *Salver-shaped*, when the tube is long and narrow with a spreading border at right angles to it (Fig. 126).

(e) *Rotate*, when the tube is very short with a spreading border (Fig. 127).

(f) *Urceolate*, or urn-shaped, when the tube is swollen below and contracted at the mouth (Fig. 128).

(g) *Labiate*, when distinctly two-lipped as in Catnip and Turtle-head (Fig. 129).

A Labiate corolla is further described as

(1) *Ringent*, when the mouth is wide open (Fig. 129).

(2) *Personate*, when the mouth is closed by an upward projection of the lower lip called the *palate* (Fig. 130).

(h) *Ligulate*, when one side of the tube is prolonged into a ribbon or strap, as in Dandelion (Fig. 119).

Fig. 121.

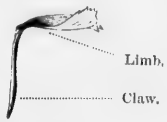


Fig. 122.

Fig. 123.

Fig. 124.

Fig. 125.

Fig. 126.

Fig. 127.

Fig. 128.

Fig. 129.

Fig. 130.

The form of corolla peculiar to plants of the Pulse Family is known as

PAPILIONACEOUS (Fig. 131): it consists of five petals; an upper large one (the *standard*), two side ones (the *wings*), and two lower ones which are united together to form the *keel*.

Finally, both gamopetalous and polypetalous corollas may have one or more petals prolonged into *spurs* at the base (Fig. 130).

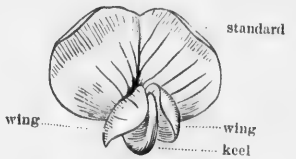


Fig. 131.

Adhesion.

HYPOGYNOUS: when inserted on the receptacle, under the ovary and free from it (Fig. 132, *c*).

PERIGYNOUS: when inserted on the calyx (Fig. 133, *c*.)

EPIGYNOUS: when inserted on the top of the ovary (Fig. 134, *c*).

The corolla should be further described by giving the shape, colour and size of the petals, using the ordinary terms.

In describing the flowers of monocotyledons having a *coloured perianth*, use the following terms for cohesion:

POLYPHYLLOUS: when the pieces of the perianth are entirely separate.

GAMOPHYLLOUS: when the pieces of the perianth are united.

For adhesion, use the terms *superior* and *inferior*, as explained above for the calyx.

Fig. 132.

Fig. 133.

Fig. 134.

Æstivation.

This term is applicable to both calyx and corolla, and means the mode in which these organs are folded in the bud. It is

(a) *Valvate*, if the edges of the parts meet without overlapping (Fig. 135), as in the calyx of Mallow.

(b) *Convolute*, if the members of a set overlap so that each has one edge covered and the other uncovered (Fig. 136), as in the corolla of Mallow.

(c) *Imbricate*, when the members of a set overlap so that at least one piece has both edges uncovered and at least one piece has both edges covered (Fig. 137), as in Apple.

(d) *Plicate* or *plaited*, applied to the folding of gamopetalous corollas. The plaits may overlap in the convolute manner, as in Fig. 138; they are then said to be *supervolute*.

Fig. 135.

Fig. 136.

Fig. 137.

Fig. 138.

THE STAMENS OR ANDRŒCIUM.

Parts.

FILAMENT: the lower stalk-like part; it supports the anther (Fig. 140). Stamens are

(a) *Exserted*, if the filaments are so long that the anthers protrude beyond the perianth (Fig. 141).

(b) *Included*, if the filaments are not long enough to raise the anthers beyond the perianth (Fig. 126).

(c) *Sessile*, if the filaments are absent (Fig. 142).

ANTHER: the swollen upper part, consisting of one or more (usually two) sacs or cells which contain the pollen (Fig. 139).

One surface of the anther is usually more deeply grooved than the other; this is the *face*, the other being the *back*.

An anther is

(a) *Introrse*, if the face is toward the centre of the flower.

(b) *Extrorse*, if turned outwards.

Attachment of the Anther.

The anther may be attached to the filament in three ways. It is

(a) *Innate*, if its lower end rests on the top of the filament (Fig. 143).

(b) *Adnate*, if the back of the anther lies with its whole length against (and attached to) the filament (Fig. 144).

(c) *Versatile*, if the end of the filament is attached to a point on the back of the anther, so that the latter swings about (Fig. 145).

Dehiscence of the Anther.

The anther may open in several ways to allow the escape of the pollen. The dehiscence is

(a) *Longitudinal*, when the anther-cell opens from top to bottom by a lateral line (Fig. 146). This is the usual mode.

(b) *By valves*, when the side of the anther-cell turns up, as on a hinge (Fig. 147).

(c) *By pores*, when the pollen escapes through a minute opening at the top of the anther-cell (Fig. 148).

CONNECTIVE: the rib or solid part between the anther-cells. Occasionally the connective is obscure or wanting.

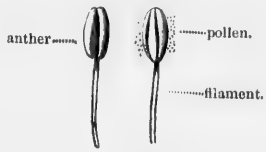


Fig. 139. Fig. 140.

Fig. 141.

Fig. 142.

Fig. 143.

Fig. 144.

Fig. 145.

Figs. 146. 147. 148.

POLLEN: the minute grains (alike in the same plant, but very different in different plants) contained in the anther-cells, commonly resembling a loose dust or powder (Fig. 140), but sometimes cohering in sticky masses (*pollinia*), as in Orchis (Fig. 149).

Pollen-grains are plant-cells having two coats, and enclosing a thickish liquid. Fig. 150 shows a single pollen-grain with its inner coat growing out in the form of a tube.

The pollen is the *essential* part of the stamen. The pupil should examine with a good microscope various kinds of pollen-grains, and make drawings of them.

Fig. 149.

Fig 150.

Number.

If the stamens are not more than *ten* in number, the exact number should be stated. If more than ten, they are *numerous* or *indefinite*, and this is indicated by the sign ∞ in the proper column of the descriptive table.

Fig. 151.

Fig. 152.

Cohesion.

If the stamens are entirely separate from each other, their cohesion (or the absence of it) is described by prefixing to the ending *-androus* the Greek prefix corresponding to the number of stamens present, as follows:

1.	2.	3.	4.	5.	6.	7.
mon-	*di-*	*tri-*	*tetr-*	*pent-*	*hex-*	*hept-*
8.	9.	10.		more than 10.		
oct-	*enne-*	*dec-*		*poly-* androus.		

The cohesion is

Fig. 153.

Fig. 154.

DIDYNAMOUS: if there are four stamens, two long and two short (Fig. 151).

TETRADYNAMOUS: if there are six stamens, four long and two short (Fig. 152).

MONADELPHOUS: when all the filaments are grown together, leaving the anthers separate, as in Mallow (Fig. 153).

DIADELPHOUS: when the filaments are grown together in two sets, as in Pea (Fig. 154).

TRIADELPHOUS: when the filaments are grown together in three sets, as in St. John's Wort (Fig. 155).

POLYADELPHOUS: when the filaments are grown together in more than three sets.

SYNGENESIOUS: when all the *anthers* are grown together, leaving the filaments separate, as in Dandelion (Fig. 155).

Fig. 155.

Adhesion.

HYPOGYNOUS: when inserted on the receptacle under the ovary (Fig. 132, *s*).

PERIGYNOUS: when inserted on the calyx (Fig. 133, *s*).

Fig. 156.

EPIGYNOUS: when inserted on the ovary (Fig. 134, *s*).

EPIPETALOUS: when inserted on the corolla (Fig. 151).

EPIPHYLLOUS: when inserted on the perianth (in Monocotyledons).

GYNANDROUS: when inserted on the style, as in Orchids (Fig. 157).

Situation.

It is important to note the position of the stamens with reference to the petals when they are of the same number as the latter. They may be

(a) *Alternate* with the petals.

(b) *Opposite* the petals.

THE PISTIL OR GYNŒCIUM.

Parts.

CARPELS: the pieces, either distinct or combined together, which make up the whole pistil. The pistil is

(a) *Simple*, if it consists of one carpel only, as in Pea (Fig. 158).

(b) *Compound*, if it consists of two or more carpels, either separate from each other *(apocarpous)* as in Buttercup (Fig. 159), or combined together *(syncarpous)* as in Fig. 160. When several carpels are combined, the number is very commonly indicated by seams or *sutures* on the outside of the ovary.

Whether composed of one carpel or several combined, the pistil may have the following parts:

OVARY: the lower swollen part, containing the ovule or ovules which develope into seeds (Fig. 160). The ovary may be one-celled even when compound (Fig. 161), or several-celled (Fig. 160). In the latter case the separating walls are called *dissepiments*, and the cells are often spoken of as *loculi* (sing. *loculus*).

STYLE: the narrow part above the ovary (Fig. 160). A compound pistil may have several styles, as in Fig. 162.

STIGMA: the moist roughish upper end of the style. This part differs from the rest of the pistil in having no skin or epidermis (Fig. 163).

The stigma is

(a) *Capitate*, if it forms a knob or button on the end of the style (Fig. 164).

(b) *Plumose*, if of a feathery appearance as in grasses (Fig. 165).

(c) *Petaloid*, if leaf-like and coloured, as in Iris (Fig. 166).

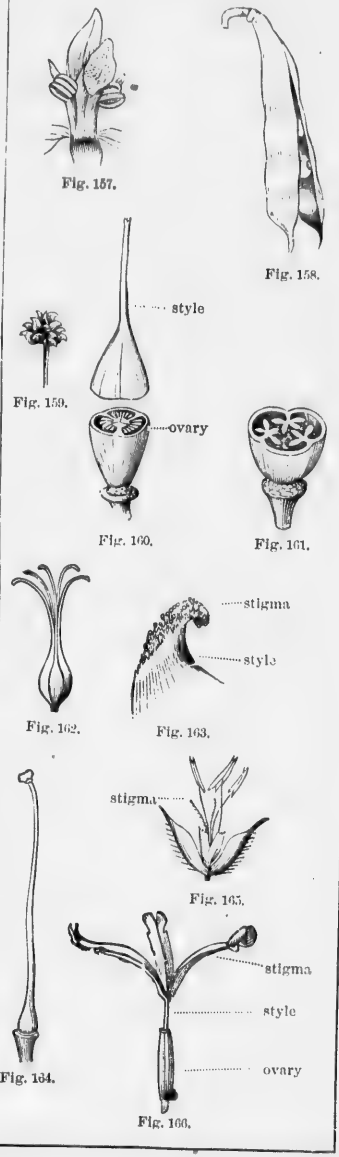


Fig. 157. Fig. 158. Fig. 159. Fig. 160. Fig. 161. Fig. 162. Fig. 163. Fig. 164. Fig. 165. Fig. 166.

Note that the essential parts of the pistil are the ovary or seed-bearing part, and the stigma which receives the pollen.

The style is often wanting, and then the stigma is *sessile*.

An exceptional pistil is found in *gymnospermous* plants like the Pine. Here the ovules are not enclosed, but are attached to the inner face of an open leaf or scale, the scales forming a *cone* (Figs. 167, 168, 169).

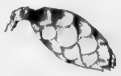


Fig. 167.

Cohesion.

APOCARPOUS: when the carpels are not united together in any way (Fig. 159).

SYNCARPOUS: when the carpels are grown together in any degree (Fig. 160). They may be united merely at the base of the ovary, or to the top of the style.

Figs. 168, 169.

Adhesion.

SUPERIOR: when entirely free from the calyx (Fig. 132, *f*), as in Buttercup, Shepherd's Purse, etc.

INFERIOR: when surrounded by the calyx-tube which grows fast to it (Fig. 134, *f*), as in Apple and Fuchsia.

THE OVULE.

Definition.

Ovules are the bodies which, after fertilization by the pollen, develope into seeds.

Figs. 170, 171.

Placentation.

By this term is meant the arrangement of the placentas, or projections in the interior of the ovary upon which the ovules grow. Placentation is

(a) *Marginal*, in a simple pistil like that of Pea, the placenta being on one seam or *suture* (Fig. 158).

(b) *Axile* or *Central*, when the pistil is compound, and the dissepiments meet in the centre of the ovary (Fig. 160.)

(c) *Parietal*, when the compound ovary is one-celled and the ovules are borne on the walls (Fig. 161).

(d) *Free Central*, when the ovary is one-celled, and the ovules are borne on a column which rises from the bottom of the cell (Figs. 170, 171).

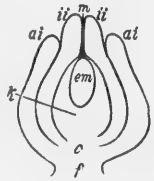


Fig. 172.

Parts of the Ovule.

FUNICULUS: the stalk by which the ovule is attached to the placenta (Fig. 173, *f*). If this stalk is absent the ovule is *sessile*.

PRIMINE: the outer coat of the ovule (Fig. 172, *ai*).

SECUNDINE: the inner coat (Fig. 172, *ii*).

MICROPYLE: the minute opening through the two coats (Fig. 172, *m*).

NUCLEUS: the body of the ovule within the coats (Fig. 172, *k*).

EMBRYO-SAC: the large cell in the nucleus in which the young plant is developed (Fig. 172, *em*).

CHALAZA: the portion where the two coats are blended together (Fig. 172, *c*).

Kinds of Ovule.

ORTHOTROPOUS: when the ovule is erect, and the micropyle is as far as possible from the funiculus or point of attachment (Fig. 172).

ANATROPOUS: when the ovule is completely inverted or bent upon itself so as to bring the micropyle close to the point of attachment (Fig. 173). In this case the funiculus becomes fused with the primine on one side, forming the raphe (Fig. 173, *r*).

CAMPYLOTROPOUS: when the ovule is half bent over (Fig. 174).

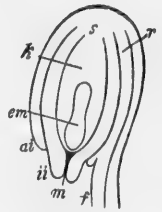


Fig. 173.

Fertilization.

Ovules are converted into seeds by the action of pollen upon them. Pollen grains fall upon the stigma which is moist and retains them. The grains begin to grow as shown in Fig. 150, the inner coat being protruded as a slender tube which makes its way down through the style into the ovary, and then through the micropyle of the ovule, finally attaching itself to the surface of the embryo-sac, and carrying the contents of the pollen-grain with it. Presently growth begins inside the embryo-sac, and soon the embryo is formed. It is the presence of the embryo which marks the distinction between an ovule and a seed.

In most cases the ovule is fertilized by pollen brought from another flower of the same species (cross-fertilization), because very commonly the pollen of its own flower is ready either too soon or too late to be of use; that is, the pollen and the stigma in the same flower do not commonly mature at the same time. Plants are

Entomophilous, when they depend upon insects to carry the pollen from flower to flower, and

Anemophilous, when this service is performed by the wind.

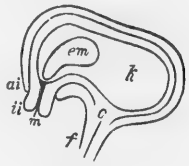


Fig. 174.

THE FRUIT.

Definition.

The fruit is the ripened pistil together with any other part, such as the calyx or receptacle, which may be adherent to it. If there are no such adherent parts the fruit is a *true fruit*, consisting wholly of the ripened ovary with the seeds; otherwise it is a *pseudocarp* or *spurious fruit*, as in Apple, Strawberry and Rose.

The essential parts of the fruit are

(a) *The Seed*, or matured ovule, and

(b) *The Pericarp*, or matured ovary, within which the seeds are contained.

The Pericarp is in three layers:

(a) *The Epicarp* (or Exocarp), the outer layer,

(b) *The Mesocarp* (or Sarcocarp), the middle layer,

(c) *The Endocarp*, the inner layer.

Kinds of Fruit.

A.—Dry Fruits: those whose pericarp remains thin, and becomes dry and hard at maturity. Such fruits are

(1) *Dehiscent*, when the pericarp opens so as to allow the seeds to escape,

(2) *Indehiscent*, when the pericarp does not so open.

Dry Dehiscent Fruits.

(a) *Follicle*, a fruit of a single carpel, which opens down one edge only, as in Marsh-Marigold and Peony (Fig. 175).

(b) *Legume*, a fruit of a single carpel, which opens down both edges (dorsal or outer and ventral or inner sutures), as in Pea and Bean (Fig. 176).

The *Loment* is a special form of legume. It is made up of a number of one-seeded joints which separate from each other when ripe; each joint, as a rule, remaining closed (Fig. 177).

(c) *Silique*, a syncarpous fruit of two carpels divided by a thin partition, from which the carpels fall away when ripe, leaving the placentas and seeds around the edge of the partition (Fig. 178).

(d) *Silicle*, a fruit of the same construction as the silique, and differing only in shape; the silique being considerably longer than broad, as in Stock (Fig. 178), and the silicle being nearly or quite as broad as long, as in Shepherd's Purse (Figs. 179, 180).

(e) *Pyxis*, a fruit which opens by a horizontal seam, so that the top comes off like a lid, as in Purslane (Fig. 181).

(f) *Capsule*, a syncarpous fruit which normally splits at maturity, either wholly or partially, into as many pieces as there are carpels.

The Dehiscence of the Capsule is

Septicidal: when the splitting takes place in the line of the dissepiments (Fig. 182).

Fig. 175.

Fig. 176.

Fig. 177.

Fig. 178.

Fig. 179.

Fig. 180.

Fig. 181.

Fig. 182.

LOCULICIDAL: when the splitting takes place in the middle of the wall of each carpel, that is, along the dorsal sutures (Fig. 183).

SEPTIFRAGAL: when the walls split away from the partition, leaving the latter standing (Fig. 184).

CIRCUMCISSILE: when the top of the pericarp comes off like a lid (Fig. 181).

BY PORES: when the seeds escape through small openings near the top of the capsule, as in Poppy.

Dry Indehiscent Fruits.

(a) *Achene*, a dry indehiscent one-seeded fruit, having the pericarp free from the seed, as in Buttercup (Figs. 185, 186), and all Composites.

(b) *Caryopsis* or *Grain*, a dry indehiscent one-seeded fruit, having the pericarp adherent to the seed, as in the Oat (Fig. 187), and Grasses generally.

(c) *Nut*, a dry indehiscent one-seeded fruit with a hard thick pericarp, and usually the product of a syncarpous pistil, in which all the cells and seeds but one have disappeared during growth.

The nut is often accompanied by a *Cupule* or hardened involucre, as in the Acorn (Fig. 188), Beech-nut and Hazel-nut.

(d) *Utricle*, like an Achene, but with a very thin loose pericarp (Fig. 189).

(e) *Schizocarp*, a dry indehiscent two-several-seeded fruit, which breaks up at maturity into one-seeded pieces (carpels), each of which, however, *remains closed*, as in Mallow (Fig. 190), and all Umbelliferous plants (Fig. 191).

(f) *Samara* or *Key*, a dry indehiscent one-seeded fruit, with a thin wing, as in Elm (Fig. 192), and Ash. The Maple (Fig. 193) has a double samara, which splits into two pieces at maturity, and so is a true schizocarp.

B.—FLESHY FRUITS (all indehiscent):

(a) *Drupe* or *Stone-fruit*, a fleshy fruit, having a very hard endocarp (the *putamen*), which encloses the seed till germination, a thick and usually juicy mesocarp, and a thin outer skin or epicarp, as the Plum, Cherry, Walnut and Peach (Fig. 194).

(b) *Berry*, a fleshy fruit, having a soft and juicy endocarp, in which the seeds are embedded, as the Grape, Tomato, Currant, etc. (Fig. 195).

The Orange is a special kind of berry known as a *Hesperidium*.

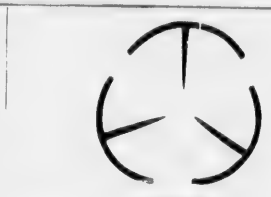


Fig. 183.

Fig. 184.

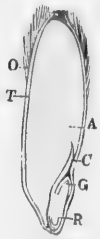


Fig. 187.

Fig. 185.

Fig. 186.

Fig. 188.

Fig. 189.

Fig. 190.

Fig. 191.

Fig. 192.

Fig. 193.

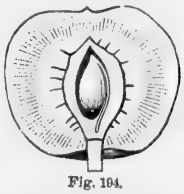


Fig. 194.

Fig. 195.

(c) *Gourd* or *Pepo*, a modified berry, having a hard rind, as in Pumpkin, Squash, etc.

(d) *Pome*, a fleshy pseudocarp, the product of a syncarpous pistil, in which the fleshy layer consists chiefly of an enlarged calyx-tube, as in Pear and Apple (Fig. 196).

(e) *Aggregated Fruit*, a clustered and coherent mass of carpels, the product of a single flower, as in Raspberry (Fig. 197).

(f) *Multiple Fruit*, a clustered and coherent mass of carpels, each carpel being the product of a separate flower, as in Pine-apple. The cone of the Pine may be regarded as a *dry* multiple fruit (Fig. 198).

(g) *Accessory Fruit*, one in which the most conspicuous part is neither a part of the pistil nor combined with it, as in Strawberry, where the conspicuous part is only the enlarged and brightly coloured receptacle, the true fruit consisting of the achenes which dot its surface (Fig. 199), and in Sweet Brier, where the fleshy outer part is a calyx-tube lined with a hollow receptacle which bears the true fruit (achenes) on its inner surface (Fig. 200).

Fig. 196.

Fig. 197.

Fig. 198.

THE SEED.

Definition.

The seed is the mature ovule, and is specially characterized by the presence of the embryo or young plantlet.

Parts.

INTEGUMENT: formed by the development of the coats of the ovule, and consisting of an outer and an inner layer.

(a) *Testa*, the outer layer (Fig. 206).

(b) *Tegmen*, the inner layer (Fig. 206).

In connection with the integument note

(1) *The Funiculus*, already defined when describing the ovule.

(2) *The Hilum*, or scar where the funiculus was attached.

(3) *The Micropyle*, a minute opening through the integument.

Also the following special appendages:

(1) *Aril*, an outgrowth of the funiculus or placenta, forming a more or less fleshy covering outside the true integument of certain seeds, as in the Climbing Bitter-Sweet and the White Water Lily (Fig. 201).

Fig. 199.

Fig. 200.

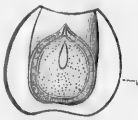


Fig. 201.

(2) *Coma*, a tuft of hairs attached to the testa in some seeds, as in Willow-herb and Milk-weed (Fig. 202).

The coma must not be confounded with the *pappus* of composite flowers; the latter is attached to the *fruit*.

(3) *Wing*, a thin expansion of the testa (Fig. 203). But in the seeds of the Pine the wing splits off from the *scale* upon which the seed grows (Fig. 168).

NUCLEUS: the body of the seed within the integument, containing

(a) *Embryo*, the young plantlet as found in the seed. This is made up of

(1) *Radicle*, the rudimentary stem (Fig. 204).

(2) *Cotyledons*, or *Seed-leaves*, the first leaves, often thick and fleshy, as in the Bean (Fig. 205), but sometimes thin and leaf-like.

(3) *Plumule*, the bud at the top of the radicle (Fig. 204).

(b) *Albumen* or *Endosperm*, when present: nourishing matter stored up outside the embryo, as shown in the shaded portion of Fig. 206, the light part in the centre being the embryo.

Fig. 202.

Fig. 203.

Fig. 204.

Fig. 205.

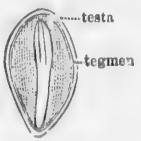


Fig. 206.

Kind.

DICOTYLEDONOUS: having two cotyledons (Figs. 207, 208, 209).

MONOCOTYLEDONOUS: having only one cotyledon (Figs. 210, 211, 212).

POLYCOTYLEDONOUS: having several cotyledons (Fig. 206). This is rare.

ACOTYLEDONOUS: having no cotyledons (rare).

ALBUMINOUS: having albumen or endosperm in addition to the embryo (Figs. 206, 210).

The following terms apply to the folding of the parts of the embryo in dicotyledonous seeds:

(a) *Accumbent*, when the radicle is turned so as to touch the edges of the cotyledons (Fig. 213).

(b) *Incumbent*, when the radicle is turned so as to lie against the back of one cotyledon (Fig. 214).

(c) *Conduplicate*, the same as *incumbent* with the addition that the cotyledons are curved so as to partly infold the radicle (Fig. 215).

Figs. 207, 208, 209.

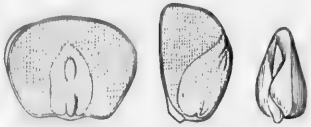


Fig. 210. Fig. 211. Fig. 212.

Fig. 213. Fig. 214. Fig. 215.

Nature and Use of the Parts of the Flower.

All the parts of the flower are leaf-forms (phyllomes), differing from ordinary foliage-leaves, *because their functions are different*.

The sepals differ less in appearance from ordinary leaves than any of the other parts. The petals resemble foliage-leaves in shape, but are mostly bright-coloured instead of green, and they are often sweet-scented. Sepals and petals together are *protective* organs, and they also serve to attract insects.

Stamens are leaf-forms in which the filament answers to the petiole, and the anther to the blade, as shown in Fig. 216.

Carpels are leaf-forms folded lengthwise more or less completely, as shown in Fig. 217.

Stamens and carpels are *essential* organs, and are directly concerned in the production of seed.

Fig. 216.

Fig. 217.

FLORAL DIAGRAMS.

By a floral diagram is meant the plan of a flower as exhibited in a cross-section. It should show the number and relative position of all the floral organs. The position of sepals, petals, and stamens is commonly easy to fix, but the true position of the carpels presents a little more difficulty. The ovary must be cut across with a sharp knife while some other organ (say the calyx) is still in position, and the relative situation of the carpels must then be carefully observed. The æstivation of calyx and corolla may also be shown to advantage in a floral diagram.

A number of examples of these diagrams are given in the margin, and the pupil should make the construction of such diagrams a regular part of his

Fig. 218.

Fig. 219.

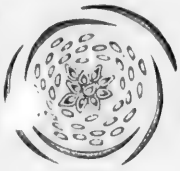


Fig. 220.

Fig. 221.

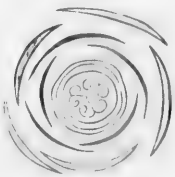


Fig. 222.

Fig. 223.

Fig. 224.

Fig. 225.

Fig. 218 is a diagram of a Mint flower.

Fig. 219 " " Leguminous flower.

Fig. 220 " " " Marsh Marigold.

Fig. 221 " " " Melon (staminate).

Fig. 222 " " " Melon (pistillate).

Fig. 223 " " " Composite flower.

Fig. 224 " " " Iris.

Fig. 225 " " " Grass flower.

LONGITUDINAL SECTIONS.

The pupil should make a constant practice of *splitting* flowers through the centre (best done from below upwards with a very sharp knife), and drawing the section thus presented. Such a drawing is exceedingly useful in connection with the floral diagram, as still further exhibiting the relation of the parts to each other.

Fig. 226 is a good example. Here the relations of the parts can be seen at a glance.

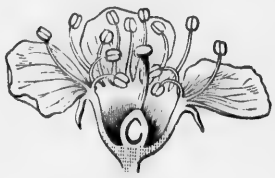


Fig. 226.

COMPOSITE FLOWERS.

A full description of a Composite flower involves some particulars of a special kind; for convenience, therefore, the various terms in use are collected together here.

Inflorescence.

Under this heading describe the arrangement of the heads, using the terms already explained—solitary, cymose, racemose, corymbose, spiked, etc.

Head.

The assemblage of florets (few or many) on a common receptacle.

Parts of the Head.

FLORETS: the small single flowers which in the aggregate make up the head. These are

(a) *Ligulate*, when the corolla is prolonged on one side into a flat strap-shaped piece (Fig. 227).

(b) *Tubular*, when the corolla is not thus prolonged, but is regularly developed all rou (Fig. 228).

RECEPTACLE: the place upon which the florets stand.

INVOLUCRE: the circle or circles of bracts which surround the head.

Fig. 227.

Fig. 228.

Fig. 229.

Kinds of Head.

LIGULIFLORAL: when all the florets of the head are ligulate, as in Dandelion (Fig. 229).

TUBULIFLORAL: when all the florets are not ligulate; and such heads are

(a) *Discoid*, if all the florets are tubular as in Thistle.

(b) *Radiate*, if the florets round the margin of the head *(ray-florets)* are ligulate, while the central ones *(disk-florets)* are tubular, as in Sunflower (Fig. 230).

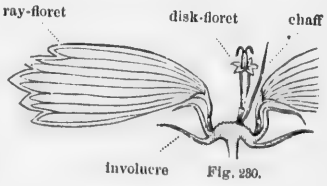


Fig. 230.

Ray-Florets (always without stamens).

NUMBER: 5, 10, 20, ∞, etc.

KIND:

(a) *Pistillate*, if the pistil is present.
(b) *Neutral*, if the pistil is absent.

SHAPE: linear, oblong, ovate, etc.

COLOUR: white, yellow, etc.

PAPPUS (if present):

(a) *Simple*, if in a single row of similar pieces.
(b) *Double*, if there is an outer row of shorter pieces.
(c) *Capillary*, of fine hair-like pieces.
(d) *Plumose*, of branching hairs or bristles, as in Thistle.
(e) *Barbed*, if the hairs have teeth pointing backward, as in Dandelion.
(f) *Chaffy*, of a few teeth or scales (Fig. 231).

Fig. 231.

ACHENE:

(a) *Compressed*, when somewhat flattened.
(b) *Terete*, cylindrical (the cross-section round).
(c) *Angled*, as in Fig. 232.
(d) *Striate*, marked with fine vertical lines.

Fig. 232.

Disk-Florets.

NUMBER: 5, 10, 20, ∞, etc.

KIND: perfect, staminate, etc.

COLOUR: yellow, brown, etc.

PAPPUS: as for the ray-florets.

ACHENE: as for the ray-florets.

Receptacle.

FORM: flat, concave, convex, conical, etc.

SURFACE:

(a) *Chaffy*, if there are chaff-like scales or bristles growing on the receptacle among the florets (Fig. 230), as in Sunflower.
(b) *Smooth*, or *naked*, if there are no such scales or bristles, as in Dandelion.

Fig. 233.

Involucre.

FORM:

(a) *Ovoid*, egg-shaped, the broader part below, as in Thistle.
(b) *Cylindrical*, nearly the same width all the way up (Fig. 233).
(c) *Saucer-shaped*, very flat and shallow.
(d) *Cup-shaped, Bell-shaped*, etc.

Bracts (or Scales) of Involucre.

NUMBER OF ROWS: state the exact number, unless very numerous.

ARRANGEMENT OF SCALES:

(a) *Imbricated*, in several rows and over-lapping (Fig. 233).

(b) *Reflexed*, turned backward, as in Dandelion (Fig. 229).

(c) *Appressed*, closely pressed together.

(d) *Squarrose*, with the points widely spreading (Fig. 233).

TEXTURE:

(a) *Herbaceous*, green and leaf-like.

(b) *Scarious*, thin and membranaceous.

SHAPE: use the ordinary leaf terms.

Fig. 234.

Fig. 235.

GRASSES.

These plants also require several special terms for their complete description. A few of the most necessary are given here.

Inflorescence.

In nearly all cases the inflorescence is a *panicle*, that is, an irregularly branched raceme, and the panicle is either loose and open, as in Meadow-grass (Fig. 238), or dense and closely packed as in Timothy and Foxtail.

SPIKELETS: the small separate clusters of flowers which together make up the panicle (Fig. 239). In some cases there is but *one* flower in the spikelet.

OUTER GLUMES: the pair of bracts at the base of the spikelet (Fig. 240). Note their shape and relative size.

INNER GLUMES OR PALETS: the pair of chaff-like bracts enclosing each particular flower (Fig. 242).

AWNS: bristle-shaped appendages sometimes found on the glumes or palets (Fig. 242).

LODICULES: small hypogynous scales next to the stamens, occasionally found in grass-flowers.

Fig. 237. Fig. 236.

Culm.

This is the name of the stem (Fig. 238). It is usually hollow except at the joints. The culms may be tufted or single, and their attitude and other characters can be described by terms already explained.

Leaf.

SHEATH: the lower portion of the leaf surrounding the stem, and split on the side away from the blade (Fig. 238).

LIGULE: a thin upward projection from the top of the sheath.

Fruit.

This always a *caryopsis* or *grain*.

TYPES OF GRASSES.

The following selection of Grasses will be found useful for examination, as illustrating most of the variations in the structure of these plants.

1. **Timothy.**

Note the close inflorescence. Separate one of the component pieces which will probably resemble Fig. 234. If fully opened out it will resemble Fig. 235. Carefully dissect and describe, making a floral diagram. The spikelet here consists of a single flower.

2. **Red-Top.**

Note the open panicle (Fig. 236). Detach and dissect a spikelet (Fig. 237), which in this plant also consists of a single flower. Observe the difference in the size of the inner bracts, and the three nerves on the larger one.

3. **Meadow-Grass.**

The inflorescence is here an open greenish panicle, but each spikelet (Fig. 239) is compressed laterally and contains from three to five flowers. Fig. 240 shows a single flower. Note the delicate whitish margin of the lower palet, and the thin texture of the upper one; also the two teeth at the apex of the latter, and the five nerves on the former.

4. **Chess.**

Here the spikelets (Fig. 241) are on long, slender, nodding pedicels, and each contains from eight to ten flowers. The glumes are different in size. Dissect out a single flower (Fig. 242) and note the awn on the lower palet. The upper palet at length grows fast to the groove of the oblong grain.

5. **Couch-Grass.**

In this grass the spikelets are sessile on opposite sides of a zig-zag peduncle, so that the whole forms a sort of spike. Each spikelet is four to eight-flowered, and there is but one at each joint of the peduncle, the *side* of the spikelet being against the stalk. Note the running root-stocks, which cause the grass to be a nuisance difficult to get rid of.

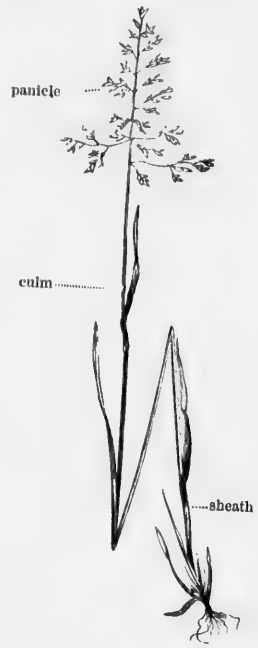


Fig. 238.

Fig. 239.

Fig. 240.

Fig. 241. Fig. 242.

6. **Old-Witch Grass.**

This grass is to be found everywhere in sandy soil and in cultivated grounds. The leaves are very hairy, and the panicle very large, compound, and loose, the pedicels being extremely slender. Of the two glumes one is much larger than the other. Unless you are careful you will regard the spikelets as 1-flowered; observe, however, that in addition to the one manifestly perfect flower *there is an extra palet below.* This palet (which is very much like the larger glume) is a rudimentary or abortive second flower, and the spikelet may be described as 1½-flowered.

7. **Barnyard Grass.**

This is a stout, coarse plant, common in manured soil. It is from one to four feet in height, and branches from the base. The spikelets form dense spikes, and these are crowded in a dense panicle which is rough with stiff hairs. The structure of the spikelets is much the same as in Old-Witch Grass, but the palet of the neutral flower is pointed with a rough awn or bristle.

8. **Foxtail.**

In the common Foxtail the inflorescence is apparently a dense, bristly, cylindrical spike. In reality, however, it is a spiked panicle, the spikelets being much the same as in Barnyard Grass, but their *pedicels* are prolonged beyond them into awn-like bristles. In this plant the bristles are in clusters and are barbed upwards. *The spikes are tawny-yellow in colour.*

Fig. 243.

THE PLANT-BODY GENERALLY,

And the Functions of its Parts.

The higher plants, such as phanerogams, are found to be made up of four distinct kinds of members, as follows:

A.—Root: embracing the ordinary subterranean forms as previously described, and certain aerial forms, together with those of parasitic plants which feed upon other living organisms. The root differs from the stem in several important respects:

(a) It is tipped with a mass of hardened cells constituting the *root-cap* (Fig. 243, *a*). This protects the young root as it makes its way through the soil, and it is replaced from the inside as fast as it is worn away on the outside.

(b) The growth of the root in length is accomplished by additions *to its extremity,* immediately behind the root-cap.

(c) Roots originate *endogenously*, that is to say, they do not develope from the exterior or surface of the plant-body, but always begin in the deeper tissues, and eventually break their way through the overlying layers till they reach the surface.

(d) They do not, as a rule, produce leaves or buds.

(e) They tend, as a rule, to grow downwards into the soil, avoiding the light.

(f) The minute structure of the root is less perfect in its development than that of the stem.

The *functions* of the root are

(a) To fix the plant in its place.

(b) To act as an absorbent of the nutritious liquids contained in the soil.

(c) In special cases to serve as a storehouse of food for the plant.

B.—CAULOME: including the stem and all its equivalents, such as branches, runners, tendrils, thorns, etc., as already described.

In contrast to the root, the stem is always preceded by a *bud*.

A bud is an early stage of the development of a stem or branch, and is found on dissection to consist of many rudimentary leaves crowded on a short axis. This axis subsequently developes *throughout its length*, forming the internodes (Fig. 244), thus differing widely from the root, which grows by additions to its extremity.

Winter-buds are covered with scaly bracts called *bud-scales*, which separate and fall away soon after the development of the bud begins in the spring.

Buds are

(a) *Terminal*, when at the ends of stems and branches.

(b) *Axillary*, when produced in the axils (Fig. 244) of leaves.

(c) *Adventitious*, when produced in some irregular manner.

(d) *Accessory*, when produced as extra or additional buds beside the regular axillary bud, so that there are really several buds in the axil.

The *functions* of the caulome are

(a) To bear leaves and flowers.

(b) To serve as a medium for the conveyance of the nourishing liquids absorbed by the root.

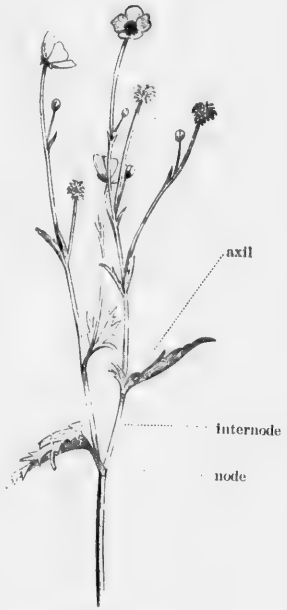


Fig. 244.

(c) In certain cases to serve as a storehouse for plant-food.

C. PHYLLOME: including the leaves and all their equivalents, such as bracts, cotyledons, bud-scales, sepals, petals, etc., as already described.

The phyllome is always developed laterally on a caulome.

Foliage-leaves (as contrasted with flower-leaves) are generally green, owing to the presence of a substance called *chlorophyll* (found also in all other green parts). A section through the body of a leaf is shown in Fig. 245, the shaded portions representing the cells which contain chlorophyll.

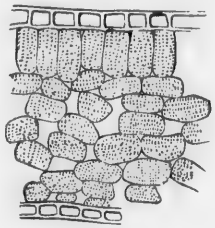


Fig. 245.

The chief *function* of foliage-leaves is to assimilate the food-materials derived from the soil and the air, thus converting them into forms (commonly starch) which can be used in advancing the plant's growth. Sunlight and chlorophyll are essential to the process of assimilation.

Transpiration. Water-vapour is given off through the leaves, by the agency of minute openings (chiefly on the under surface) known as *stomata* (singular *stoma*). One of these greatly magnified is shown in Fig. 246. These stomata communicate with air-spaces among the loosely-packed cells in the body of the leaf. It may often be observed in hot bright weather that the leaves of plants droop if exposed to the sun; this is because the loss of water through the leaves is greater than the supply through the roots. At night, however, the stomata close, and the balance being restored the plant recovers.

Fig. 246.

The functions of flower-leaves have already been referred to.

D.—TRICHOME: including all the outgrowths from the surface or epidermis, whether of stem, leaf or root, such as hairs, bristles, root-hairs, prickles, etc.

Fig. 247.

Of all the trichome structures the root-hairs which occur abundantly on the young roots of most plants, are the most important. They consist of single long cells, and their function is to increase the absorbing surface of the root, for which service they are peculiarly fitted by the thin and delicate nature of their walls.

Hairs on parts above ground usually consist of a row of cells placed end to end (Figs. 247, 248). Often they are branched, as in the leaf-hairs of the Mullein.

Fig. 248.

Glandular hairs secrete a liquid in the cell which occupies the extremity of the hair. The sticky surfaces of certain plants are produced in this way.

Stinging hairs secrete a poisonous liquid. The point of a hair of this kind on piercing the skin breaks off, leaving the poison in the wound.

Prickles (Fig. 249) differ from *thorns* in being outgrowths of the bark; thorns arise from the wood.

GROWTH.

The growth of a plant consists in the multiplicatlon of its cells, and the subsequent enlargement of the latter by the addition of new matter. The development of the cell frequently involves, also, a change of form.

Germination.

By this term is meant the commencement of the process of growth from the seed. Under suitable conditions of temperature and moisture the embryo, which is dormant in the dry seed, wakens into activity and begins to develope. The details of the process vary somewhat according to the structure of the seed. If the cotyledons are thin and leaf-like, as in Maple for example, the radicle generally grows throughout its length so as to raise them above the soil, where they at once expand and become the first green leaves of the new plant, a root being at the same time developed from the lower end of the radicle. But if the cotyledons are thick and fleshy, containing much nourishment, then usually a bud called the plumule, which contains the elements of additional bits of stem, will be a prominent feature in the embryo, and in this case the cotyledon or cotyledons not infrequently remain under ground, as in the pea and the acorn, and so do not perform the office of foliage-leaves, but merely supply the newly developing parts with nourishment. In albuminous seeds, the endosperm is the chief source from which the germinating embryo derives its support.

Vitality of Seeds.

There is a considerable difference in regard to the length of time during which seeds retain their vitality. Some, such as those of Elm and Poplar, will germinate only if they have been kept fresh and not permitted to dry up, while others, such as those of Indian Corn and Wheat, and in general those containing a copious store of starch, may be kept for a very long time without losing their germinating power.

Food of Plants.

Growth implies assimilation of food. The elements of plant-food are ascertained by making a chemical analysis of the plant itself. Water forms a very considerable percentage of the whole weight, but is present to a greater extent in some portions of the plant body than in others. Fleshy roots, for example, may contain as much as 90 per cent., while dry seeds contain only about 12 per cent.

The water may be expelled by careful drying, and if what is then left is burnt, what is called the *organic* part of the plant disappears, and the *inorganic* part (the ash) remains behind. The organic part consists mainly of the elements carbon, hydrogen, oxygen, nitrogen, and sulphur; while the inorganic part contains very small quantities of phosphorus, iron, calcium, magnesium, and potassium. Of all these constituents of the *dry* plant carbon is the most abundant, amounting to about half the entire weight.

Sources of Plant-food.

All the materials just mentioned are obtained from the air, the water, and the soil. There is constantly present in the air carbonic acid gas—a compound of carbon and oxygen. This is absorbed by the leaves of land-plants, and (being soluble) from the water in which they live, by immersed plants. After absorption the gas is decomposed and the carbon appropriated. The oxygen required by the plant is derived chiefly from the carbonic acid gas and from water. Hydrogen is obtained chiefly by the decomposition of water, and nitrogen from the nitrates and ammonia salts in the soil. Sulphur, also, is obtained from salts occurring in the soil, and so too, of course, are all the inorganic elements

Respiration.

Plants, like animals, are continually inhaling oxygen; indeed, as with animals, oxygen is essential to their existence. Germinating seeds and growing parts require large quantities of oxygen. The gas when inhaled is combined with carbon, giving rise to carbon dioxide. This process of oxidation is always accompanied by evolution of heat. This is well illustrated in the process of malting, where damp barley is heaped together. As soon as the grain begins to sprout oxygen is rapidly absorbed, and a very decided rise of temperature takes place.

Assimilation.

This is the process by which the carbon obtained from carbon dioxide is combined with the elements of water to form starch.

Metastasis.

This is the process by which the starch, resulting from assimilation, is converted into soluble forms and removed from the cells where it was produced to other portions of the plant where it is needed for purposes of growth, or, if there is an excess, to storehouses such as roots, bulbs, etc., for future use.

Circumstances Affecting Growth.

Temperature.—Growth may be stopped altogether by either too low or too high a temperature, and between the limits within which any given plant is found to be capable of growth there will be found a particular degree of temperature more favourable to growth than any other, either above it or below it. This may be called the *optimum*. The effect of temperature diners considerably according to the amount of water present in the part affected, dry seeds, for instance, resisting a temperature, either high or low, to which soaked seeds would at once succumb.

Light.—Light is essential to assimilation, but seeds and tubers, as well as many of the lower plants which are without chlorophyll, such as Mushrooms, will grow in the absence of light as long as the stock of assimilated material upon which they draw is not exhausted. The growth which takes place in the cambium-layer of dicotyledons and in roots is another example of increase in size in the absence of light. The assimilated material in all these cases, however, has been previously elaborated elsewhere.

Light is found to exercise a retarding influence upon growth. A plant, for instance, in a window will bend towards the light, because the cells on the side nearest the window grow more slowly than those which are shaded. thus causing curvature of the stem and petioles.

Gravitation.—Gravitation also affects growth, as we know that the stem and root, or *axis* of the plant, are usually in the line of the radius of the earth at the place of growth. If a seedling plantlet be laid with the stem and root horizontal, the stem will curve upward and the root downward in the endeavour to restore the vertical direction.

THE HERBARIUM.

Those who are anxious to make the most of their botanical studies will find it of great advantage to gather and preserve specimens for reference. A few hints, therefore, on this subject will not be out of place. It will, of course, be an object to collectors to have their specimens exhibit as many of their natural characters as possible, so that, although dried and pressed, there will be no difficulty in recognizing them; and to this end neatness and care are the first requisites.

Collecting.

Specimens should be collected when the plants are in flower, and, if possible, on a dry day, as the flowers are then in better condition than if wet. If the plant is small, the whole of it, root and all, should be taken up; if too large to be treated in this way, a flower and one or two of the leaves (radical as well as cauline, if these be different) may be gathered.

Drying.

As many of your specimens will be collected at a distance from home, a close tin box, which may be slung over the shoulder by a strap, should be provided, in which the plants may be kept fresh, particularly if a few drops of water be sprinkled upon them. Perhaps a better way, however, is to carry a portfolio of convenient size—say 15 inches by 10 inches—made of two pieces of stout pasteboard or thin deal, and having a couple of straps with buckles for fastening it together. Between the covers should be placed sheets of blotting-paper or coarse wrapping-paper, as many as will allow the specimens to be separated by at least five or six sheets. The advantage of the portfolio is, that the plants may be placed between the sheets of blotting-paper, and subjected to pressure by means of the straps as soon as they are gathered. If carried in a box, they should be transferred to paper as soon as possible. The specimens should be spread out with great care, and the crumpling and doubling of leaves guarded against. The only way to prevent moulding is to place plenty of paper between the plants, and *change the paper frequently;* the frequency depending on the amount of moisture contained in the specimens. From ten days to a fortnight will be found sufficient for the thorough drying of almost any plant you are likely to meet with. Having made a pile of specimens with paper between them, as directed, they should be placed on a table or floor, covered by a flat

board, and subjected to pressure by placing weights on the top; twenty bricks or so will answer very well.

It is of great importance that *the sheet of paper within which the plant is first placed* should not be interfered with during the drying process. The directions as to frequent changes refer only to the sheets not immediately in contact with the plant. These, to ensure the best results, should be changed once a day for the first few days; less frequently thereafter. Gray recommends ironing with hot irons in order to remove more rapidly the moisture from fleshy leaves, and in any case to warm the driers in the sun before putting them between the plants.

Mounting.

When the specimens are thoroughly dry, the next thing is to mount them, and for this purpose you will require sheets of strong white paper; a good quality of unruled foolscap or cheap drawing paper will be suitable. The most convenient way of attaching the specimen to the paper is to take a sheet of the same size as your paper, lay the specimen carefully in the centre, wrong side up, and gum it thoroughly with a very soft brush. Then take the paper to which the plant is to be attached, and lay it carefully on the specimen. You can then lift paper and specimen together, and, by pressing lightly with a soft cloth, ensure complete adhesion. To render plants with stout stems additionally secure, make a slit with a penknife through the paper immediately underneath the stem, then pass a narrow band of paper round the stem, and thrust both ends of the band through the slit. The ends may then be gummed to the back of the sheet.

Sorting and Ticketing.

The specimen having been duly mounted, its botanical name should be written neatly in the lower right-hand corner, together with the date of its collection and the locality where found. Of course only one Species should be mounted on each sheet; and when a sufficient number have been prepared, the Species of the same Genus should be placed in a sheet of larger and coarser paper than that on which the specimens are mounted, and the name of the Genus should be written outside on the lower corner. Then the Genera of the same Order should be collected in the same manner, and the name of the Order written outside as before. The Orders may then arranged in accordance with the classification you may be using, and carefully laid away in a dry place. If a cabinet, with shelves or drawers, can be specially devoted to storing the plants, so much the better.

ON THE MINUTE STRUCTURE OF PLANTS.

The Cell—Tissues—Tissue-Systems—Exogenous and Endogenous Stems.

Up to this point we have been engaged in observing such particulars of structure in plants as are manifest to the naked eye. We shall now enquire a little more closely, and find out what we can about the *elementary* structure of the different organs. We have all observed how tender and delicate is a little plantlet of any kind just sprouting from the seed; but as time elapses, and the plant developes and acquires strength, its substance will, as we know, assume a texture varying with the nature of the plant, either becoming hard and firm and woody, if it is to be a tree or a shrub, or continuing to be soft and compressible as long as it lives, if it is to be an herb. Then, as a rule, the leaves of plants are of quite a different consistency from the stems, and the ribs and veins and petioles of foliage-leaves are of a firmer texture than the remaining part of them. In all plants, also, the newest portions, both of stem and root, are extremely soft compared with the older parts. It will be our object now to ascertain, as far as we can, the reason of such differences as these; and to accomplish this we shall have to call in the aid of a microscope of much higher power than that which has hitherto served our purpose.

Fig. 250

Fig. 251.

The Cell.

First let us examine under our microscope a very thin slice of the pith of the Elder. You see at once that the whole slice is made up of more or less rounded, nearly transparent bodies, rather loosely thrown together, as shown in Fig. 250. Next let us examine, in the same way, a thin slice of the tuber of the Potato. Here, again, it is evident that the object under examination is wholly composed of enclosed spaces, not so much rounded, however, as those of the Elder pith, because they are more closely packed together. Fig. 251 is a representation of two of these spaces. Now look at the leaf of a Moss, and you see again that we have an aggregation of enclosed spaces as before (Fig. 252). So, also, if we examine a hair from the surface of a Petunia or a Geranium, we have some such appearance presented to us as that shown in Figs. 253 and 254, the hairs manifestly consisting of several enclosed spaces placed end to end. In short, the microscope reveals to us the fact that every part of a plant is made up of such enclosed spaces, varying greatly in shape and size and general aspect, it is true, but always (except in some of the very lowest plants) clearly exhibiting boun-

Fig. 252.

daries; and since these boundaries are visible, no matter in what direction we make our cutting, it is clear that the spaces must be shut in on all sides. These enclosed spaces are called *cells*, and their boundaries are known as the *cell-walls*.

Protoplasm.

Whilst looking at the parts of plants just submitted to examination, it must have struck you that the interior of the cell presents a very different appearance in different cases. The Potato section, for example, is not at all like the Moss-leaf section in the matter of *cell-contents*, and the cells of the Elder-pith appear to be quite empty. We shall discuss these differences presently. In the meantime let us study the appearance of some cells taken fresh from some part of a plant where growth is actually going on—say the point of a new rootlet. If a section is taken near enough to the point we shall get cells which have been just formed. Such a section is very well shown in Fig. 255. Here the cells are seen to be completely filled with liquid having a granular appearance, and in the centre of each a rounded denser portion may be made out, each of these again enclosing one or more small bodies. This liquid which thus fills the newly-formed cell is called *protoplasm* (*p*), the large rounded central mass is the *nucleus* (*h*), consisting of denser protoplasm, and the smaller enclosed masses are the *nucleoli* (*kk*).

Fig. 254.

Fig. 255.

Now let us consider Fig. 256. This is a representation of a section of the same rootlet, taken a little farther back from the point, so that the cells now in view are a little older than the first ones. They are manifestly larger; that is to say, they have *grown*. The nucleus and the nucleoli can still be made out in some of them, but the protoplasm no longer entirely fills the cell. There are now transparent spaces (*vacuoles* [*s*]) which are filled with water, and between these the protoplasm is seen in the form of strings or bands, as well as lining the cell. The water has been absorbed through the cell-wall, and after saturating the protoplasm the excess has formed the vacuoles.

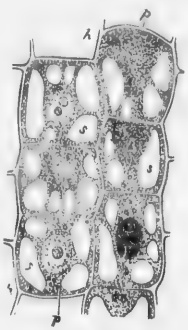


Fig. 256.

Fig. 257 shows some cells from the same rootlet taken still farther back. It is clear that the change observed in Fig. 256 has been carried to a still greater extent. In some of these cells the protoplasm is restricted to the lining of the cell and the nucleus. In this figure *h* is the cell-wall; *s*, *s*, vacuoles; *p*, protoplasm; *k*, nucleus.

It is now to be observed that the protoplasm is the essential part of every living cell. Through its agency all the vital processes of the plant are carried on. Every cell of

every plant at some time or other contains this substance, and when at length it disappears, the cells which are deprived of it no longer take any active part in the growth of the plant, but serve merely mechanical purposes, such as that of support or conduction, and are, in that stage of their history, filled usually with air or water. The pith of the Elder is made up of such dead cells, as is also the greater part of the wood and bark and older parts generally of all plants.

The most marked feature of the living protoplasm is its *activity*. We may observe this property by examining plant-hairs and other parts under high powers of the microscope, when it will be seen that there are movements of two kinds. The whole mass of protoplasm has a rotary motion, sliding upon the cell-wall, downwards on one side and upwards on the other. This is the *mass-movement*. Also currents may be traced passing across the protoplasm in different directions. This is the *streaming-movement*. In Fig. 258 the arrows show the direction of the currents.

In some of the very lowest plants, where there is no cell-wall, and the whole is a mass of naked protoplasm, these movements may be observed more readily because they are less restricted.

There is some doubt as to the exact chemical composition of protoplasm. It is, however, a very complex substance belonging to a group of bodies known as *albuminoids*, of which nitrogen is an important constituent.

The consistence of protoplasm depends upon the amount of water it contains. In dry seeds, for example, it is tough and hard, but when the same seeds are soaked in water it becomes partially liquid.

Forms of Cells.

As cells become older they tend as a rule to change their form, though sometimes we find them differing but little from their original conformation. Commonly a cell grows more rapidly in some one direction, thus giving rise to long forms, as is the case in stems generally, and in the petioles and veins of leaves, the superior toughness and strength of which are due to the lengthening and hardening of the cells of which they are composed (Fig. 259).

The Cell-wall.

In the portions of plants just selected for microscopic examination we have seen that the protoplasm is in every instance bounded by a wall. It has been ascertained that the wall is a chemical compound of carbon, hydro-

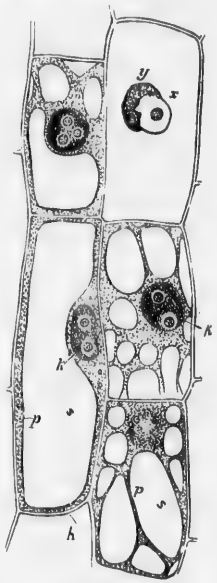


Fig. 257.

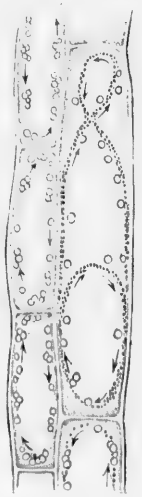


Fig. 258.

Fig. 259.

gen and oxygen, and to this compound the name *cellulose* has been given.

We have said that the protoplasm is the active principle through the agency of which all the vital processes of the plant are carried on. It contains at some time or other every constituent of the plant. The cell-wall is itself, therefore, a product or *secretion* of the protoplasm, and is at first an extremely thin film, which, however, gradually increases in thickness by the addition of further material. This new material is deposited *between the molecules* of the original film, and so extends not only the surface of the wall, but, by deeper deposits, the thickness also. This process of acquisition of new material is known as *intussusception*.

As the wall between two cells increases in thickness, a distinct middle layer is discernible in it, known as the *middle lamella* (*m*, Fig. 260). This portion of the common wall is different in chemical composition from the rest, so that it may, under proper treatment, be dissolved and the the cells thereby separated.

It is in the earlier stages of their history, while the walls are comparatively thin, that the cells possess the greatest activity. By these alone is carried on the process of growth, which consists in the multiplication and enlargement of cells.

It is seldom the case that the wall is thickened uniformly. Often numerous round thin spots are left, so that the cell has a *dotted* appearance (Fig. 261). When the thin spots in adjacent cells are contiguous, as they commonly are, a ready means of intercommunication is afforded. Sometimes the spots, instead of being round, are oblong, so that the cell under the microscope presents a *ladder-like* appearance, and so is said to be *scalariform* (Fig. 262). Then, again, the thickening may take the form of *spiral bands* upon the inner surface; or, instead of a continuous spiral band, we may find a series of *isolated rings*, when the marking is said to be *annular*. *Reticulated* cells are also found, in which the markings, as the name implies, form a sort of network on the walls. Several of these forms are shown in Figs. 263 and 264.

Sometimes round thin spots will be left in the wall, and over each of these a thick-walled dome with an opening at the top will be formed. At the same time a similar dome is raised at exactly the same spot on the other side of the wall in the next cell; and, finally, the thin partition between the opposite domes break away, permitting free communication. Thus are formed what are called *bordered pits* (Fig. 265), which abound in the wood of Coni-

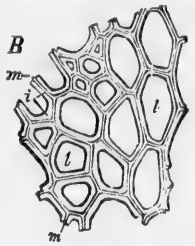


Fig. 260.

Fig. 261.

Fig. 263. Fig. 264.

Fig. 262.

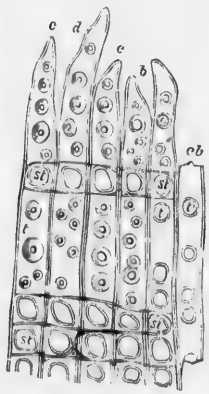


Fig. 265.

fers. Fig. 266 is a diagram showing the structure of these peculiar markings.

When cells stand end to end, and thin spots are left in the cross-partitions between them, *sieve-cells* are formed. Here, again, the thin spots finally disappear, thus practically uniting adjacent cells. Fig. 267 illustrates these cells. Here *ps* represents the shrunken protoplasm (lifted off the perforated cross-partition at *sp*); *si*, a sieve-plate on the side-wall. On the right is a view of the sieve-like wall.

It sometimes happens that the thickening takes place throughout the length of a cell but in its *angles only*. Cells of this kind, which are often found immediately under the surface of the stem in the higher plants, are called *collenchyma* cells. Fig. 268 is a transverse section of a petiole of a Begonia leaf, showing collenchyma cells; *e* is the epidermis, *chl* chlorophyll granules.

Besides the markings on the inside, cells often show markings on the outside. The pollen-grains of the Mallow, for instance, are seen under the microscope to be covered with pointed projections. Other pollen-grains, also, exhibit outside markings of different sorts.

The thickening deposit may be so excessive in some cases as to almost completely fill up the cavity of the cell (Fig. 269). The shells of nuts and the tough coatings of seeds consist of cells of this kind; but even in these cases the wall may be seen to be traversed by slender pores or canals, either simple or branched, radiating from the centre of the cell. To these hardened cells the name *sclerenchyma* is applied.

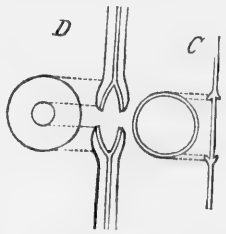


Fig. 266.

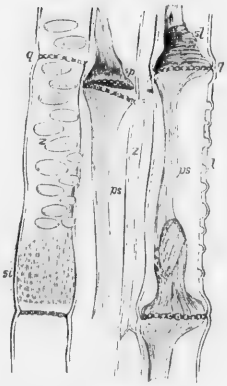


Fig. 267.

The Contents of Cells.

If you look at Fig. 252, or, better still, if you have the opportunity of viewing a Moss-leaf through a good microscope, you will see that in the protoplasmic lining of the cells there are numerous greenish, rounded granules. These are the bodies to which the green parts of plants owe their colour. They are called *chlorophyll-granules*, and consist of protoplasmic matter in which particles of green colouring matter are embedded. The colouring matter itself is chlorophyll, and may be dissolved out of the granules, leaving the latter as ordinary protoplasm. Almost without exception chlorophyll requires the action of sunlight for its production, and the chlorophyll disappears from green parts when sunlight is withdrawn, as is well seen in the process of bleaching celery. In many of our brightly coloured foliage-plants the chlorophyll is concealed from view by other colouring matters. In flowers various colours are found in the protoplasm, but

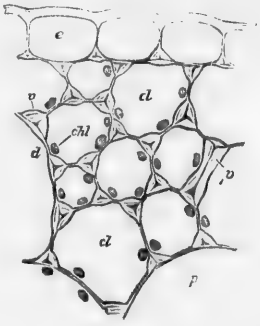


Fig. 268.

these, unlike chlorophyll, are produced in darkness as well as in sunlight.

Chlorophyll is of the utmost importance to the plant, seeing that only in the cells which contain it, and in the presence of sunlight, can the materials which the plant imbibes from the soil and the air be *assimilated*, that is, converted into matter which the plant can use for the purposes of growth.

Now consider Fig. 251. Here are exhibited cell-contents of an entirely different aspect. The rounded bodies here visible are *starch-granules*, as may be easily demonstrated by adding a drop of iodine solution to the Potato section under the microscope, a characteristic blue colour being at once produced. Such granules, differing somewhat in shape in different cases, abound in the cells of tubers and grains of all sorts, where they have been stored up for use during the process of germination. They are originally formed during sunlight in the chlorophyll granules of the green parts. When the light is withdrawn, as at night, they are dissolved and carried in solution to other parts to promote growth or to be stored up. If starch-granules are subjected for a time to the action of saliva it will be found that a portion of each granule has been dissolved out, leaving an insoluble skeleton behind. The granule is thus shown to be made up of two distinct parts, the more soluble portion being known as *granulose*, and the less soluble framework as *starch-cellulose*.

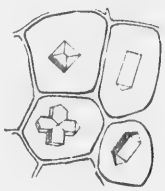


Fig. 269.

Crystals.

These are of common occurrence in many plants, not only in the cell-cavities, but also imbedded in the substance of the cell-wall. They are also of various shapes, and may either occur separately or be massed together in clusters. The needle-shaped forms are known as *raphides*. These crystals consist for the most part of calcium oxalate, but calcium carbonate is also found, and may be readily distinguished from the former by the effervescence occasioned on the addition of hydrochloric acid. The oxalate dissolves in this acid without effervescence.

Crystals may be readily observed under the microscope in thin sections of scales from the Onion bulb (Fig. 269), Rhubarb, Indian Turnip, and many other plants.

In the leaves of plants of the Nettle Family it frequently happens that a wart-like growth of cellulose takes place on the inside of the cell-wall, the inwardly projecting mass being attached to the wall by a slender stalk, and having multitudes of small crystals imbedded in it. Such inward growths are called *cystoliths;* they may be readily seen in cross-sections of the Nettle leaf.

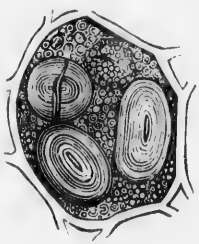


Fig. 270.

Crystalloids.

Seeds, especially those of an oily nature, as they approach maturity and become dry, develope in their cells multitudes of small rounded bodies of an albuminous nature known as *aleurone-grains* (Fig. 270), and these often envelope minute substances of crystalline aspect, which, however, under the action of potash and other re-agents, undergo such changes of form as to lead to the belief that they are not true crystals. They are called *crystalloids*, and are to be regarded as forms of protoplasm.

Occasionally crystalloids are observed without the albuminous envelope, as, for example, in the tuber of the Potato. Fig. 251 shows a cell having two or three such crystalloids of a cubical shape.

The aleurone-grains in seeds containing starch fill the spaces between the starch-granules, as shown in Fig. 270, which represents a cell from the cotyledon on the Pea. In oily seeds, such as the Brazil-nut, they replace the starch.

Other Cell-contents.

Besides the important substances already enumerated as products of the protoplasm, many others are found, such as sugar, inuline (a substance nearly related to starch, and found in a few special plants), fixed oils (castor, olive, linseed, etc., chiefly in seeds), essential oils (turpentine, oil of lemons, and essences of different kinds), gums, resins, and various acids.

How new Cells are formed.

There are several methods by which new cells are produced, but in the higher plants the common method is that of *cell-division*. We have already stated that only the newer thin-walled cells are capable of exercising this function. The process is briefly as follows: in the cell about to divide, the protoplasm first separates into two portions, each containing part of the nucleus; then a partition-wall of cellulose is developed between the two portions, thus forming two cells out of the original one. Each part then enlarges and divides again, and so the process goes on. When cell-division takes place in one direction only, *filaments* or *threads* are formed; if in two directions, *surfaces* are formed; while division in three directions gives rise to *masses*. Fig. 271 shows dividing cells of the Bean in different stages.

It is evident that every part of a plant, however much altered in its later history, must in its earlier stages have consisted of this thin-walled cellular substance, or *meristem*, as it is called from its power of dividing.

Cell-division, then, is the method of new cell formation which prevails in the vegetative parts of the higher plants. In

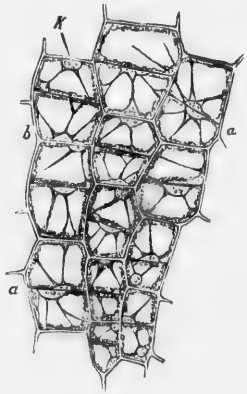


Fig. 271.

the production of pollen, however, and of the spores of vascular cryptogams, four new nuclei are formed in the cell, and the protoplasm collects about these, eventually secreting walls, so that four new and complete cells are formed *within* the original one, and these sooner or later make their escape. This mode is known as *free cell-formation*. Fig. 272 shows the formation of pollen-grains of Hollyhock in four stages. In the production of the endosperm cells in the embryo-sac, and the spores of many of the lower plants, a similar process goes on; but here the division of the nucleus is not limited to four portions, as in the cases just mentioned, but may be carried on to an indefinite extent.

In some lower plants the entire contents of two adjacent cells may coalesce to form a single new cell. This mode is known as *conjugation*. Fig. 273 shows this process in Spirogyra. At *a* the fusion of the protoplasm is going on; at *b* it is complete. Also, the contents of a cell may contract and develope a new cell-wall, a process known as the *rejuvenescence* or renewal of a cell.

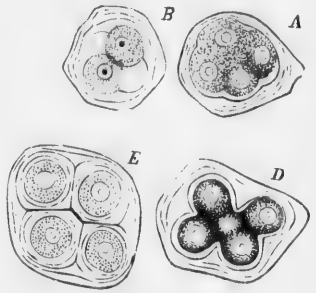


Fig. 272.

Tissues.

An aggregation of similar cells is called a *tissue*. Originally, every part of a plant consists of *meristem*, that is, of cells capable of dividing. But changes set in, as we have seen, at a very early stage, and eventually all the cells assume *permanent* forms, some developing in one way, others in quite a different way, according to the function of each particular part. So that in any given plant we find tissues, or groups of cells, of very various kinds, and very different arrangements of these tissues in different cases. By examining sections taken in succession from the growing point backwards, every degree of change from meristem to permanent tissue may be made out.

In the growing parts of all plants, in the pulp of fruits, in the pith, in the green parts of leaves, and in the entire substance of many plants of low organization, we find tissue composed of short and comparatively thin-walled cells, to which the name *parenchyma* has been given. On the other hand, in the substance of wood, in the inner bark, in the petioles and veins of leaves, etc., we meet with tissue consisting of long, pointed and overlapping cells, and known as *prosenchyma*. That of the wood is *fibrous* tissue, and that of the inner bark is the *bast*, specially characterized by the extraordinary length and flexibility of the cells. *Sclerenchyma* and *collenchyma* have already been referred to. In the former the cells are commonly, though not always, short; while in the latter they are usually long, but the ends are not pointed.

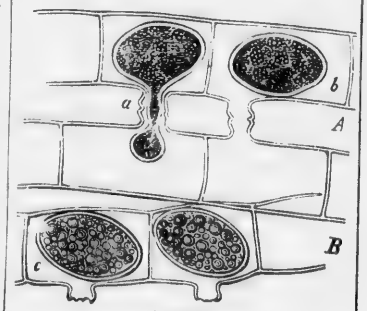


Fig. 273.

Cells have been described which are characterized by peculiar markings on their walls. When such cells stand end to end, the cross-partitions commonly disappear, with the effect of forming long tubes, generally of larger diameter than the other cells with which they are associated. Such large cells are known as *vessels*, and tissue formed of them is called *vascular* or *tracheary* tissue. Hence we have *spiral*, *scalariform*, *annular*, *reticulated*, and *dotted* vessels. These different kinds of vessels are usually found associated with fibrous tissue, and the combination of the two is known as the *fibro-vascular system*.

Many plants, such as Dandelion, Blood-root, Milkweed, and Spurge, emit a coloured or milky juice when wounded. This juice is technically called the *latex*. It is contained in a special tissue which is peculiar to such plants, known as *laticiferous* tissue (Fig. 274). Its form differs in different cases. In some instances it consists of long tubes which may or may not branch. In others, the cells composing it form a net-work. As in the case of vessels, the latex tubes are commonly formed by the coalescence of cells originally separate, but sometimes by the continued apical growth of single cells.

Fig. 274.

Sieve-tissue

has been already noticed. The cells are usually rather wide, and the walls are not hardened, but the cross-partitions between the cells are thickened and perforated.

It may be added that *single cells* which resemble vessels in their markings are often spoken of as *tracheids* (Fig. 265).

Tissue-Systems.

While groups of similar cells are designated tissues, we may have also different combinations of these tissues in different plants, or in different parts of the same plant, and these various combinations are known as *tissue-systems*. These are now usually ranged under three heads: (1) *The Epidermal System*, including those combinations of tissue which go to form the coverings of young stems, roots, and leaves; (2) *The Fibro-vascular System*, including such combinations as form the stringy masses which abound in the substance of the higher plants; and (3) *The Fundamental System*, including the combinations of cells which have undergone little or no change of form; in short, all the rest of the plant except the two systems first mentioned.

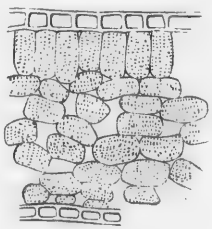


Fig. 275.

The Epidermal System

is most highly developed in Phanerogams. Fig. 275 shows a section through the thickness of a leaf. Here it will be observed that there is a closely-packed layer of cells

forming the upper surface, and a similar layer forming the lower surface. These layers constitute the *epidermis* or skin of the leaf. The outer part of the epidermis is usually a continuous layer, and is known as the *cuticle*. It will be seen that the walls of these cells are much thicker than those of the cells in the body of the leaf, and also that the epidermal cells, unlike the interior ones, have been emptied of their protoplasmic contents and are rectangular in shape. It sometimes happens that the epidermis consists of two or three layers instead of one.

The outgrowths of the epidermis, included under the general term *trichomes*, have already been referred to; they must be regarded as part of the epidermal system.

An examination of the under surface of almost any leaf will show the presence of a large number of oval openings, somewhat similar to that shown in Fig. 277. These are *stomata* (*s*, Fig. 276). They are formed by two epidermal crescent-shaped cells with a space between them, and these have the power of separating or closing together according to circumstances; separating in the light, in moist weather, and closing in dry. The openings communicate with *intercellular spaces* in the body of the leaf, a number of which are seen in Fig. 275. Fig. 278 is a larger view of a fully formed stoma (*s*). In ordinary leaves with an upper and a lower surface, the stomata are far more numerous on the lower side; indeed, many such leaves are entirely without stomata on the upper surface. Vertical leaves have them rather equally distributed on both surfaces. Immersed leaves and underground stems have hardly any at all, and they are never found on roots.

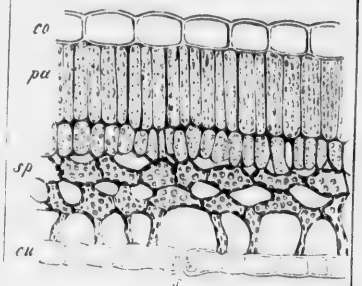


Fig. 276.

Fig. 277.

The stems of Dicotyledons lose their epidermis at a comparatively early period, and a tissue consisting of cells of *cork*, filled with air, takes its place. These cork-cells are modifications of the cells beneath the epidermis, and they form an effectual protection to the tissues within. The skin of the Potato-tuber exhibits this corky layer very clearly. The special tissue from which the cork is developed is called *phellogen*.

Fibro-Vascular System.

In the Fibro-vascular System different plants exhibit a very different arrangement of the component tissues. As a rule, these tissues are capable of division into two groups, in one of which the wood is developed, and in the other the bast. To the former of these groups the general term *xylem* is applicable, and to the latter the term *phloem*. The xylem is made up of the elongated woody cells with pointed and overlapping ends, already referred to as fibrous

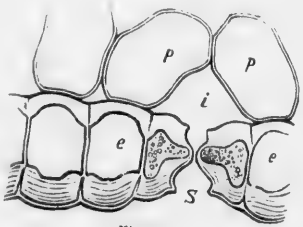


Fig. 278.

tissue, the wide tubes (vessels) with variously marked walls, formed by the disappearance of the cross-partitions between cells placed end to end, and more or less short-celled tissue or parenchyma. The phloem is likewise made up of three constituents: the long, thick-walled, flexible cells called bast cells, which correspond to the fibrous tissue of the xylem; the wide, thin-walled sieve-cells corresponding to the vessels; and a certain amount of thin-walled parenchyma.

The fibro-vascular *bundles*, as they are called, have their origin in the meristem of the growing point. This meristem is at first uniform, but soon groups of long cells arise in it, and these are then known as *procambium*, to distinguish them from the surrounding ground-tissue. This procambium is gradually converted into the fibro-vascular bundles.

Fig. 279.

In dicotyledonous plants, the fibro-vascular bundles are more or less wedge-shaped, as shown in Fig. 279. The inner part of each bundle consists of xylem and the outer of phloem, and between the xylem and the phloem there is a layer of meristem, known as the *cambium*. The soft cells of the cambium divide, and the new cells thus continually being formed become modified on the one hand into tissues which increase the thickness of the xylem, and, on the other, into tissues which are added to the phloem. Later on cambium cells are formed in the ground-tissue between the bundles, thus linking together the cambium-layers of the various bundles, and forming a continuous ring. The links are then known as *inter-fascicular* cambium, that of the bundles themselves being the *fascicular*. Bundles of this kind, characterized by the cambium-layer, and so capable of continuous enlargement, are called *open* bundles. Fig. 280 illustrates the structure of the dicotyledonous stem. M is the pith; R is the cortex; *x*, xylem, and *p*, phloem of each bundle; *fh*, wood formed by fascicular cambium; *ifh*, wood formed by interfascicular cambium; *ifp*, interfascicular phloem; *b*, *b*, *b*, bast-fibres; *fc*, fascicular, and *ic*, interfascicular cambium. The external ring represents the epidermis.

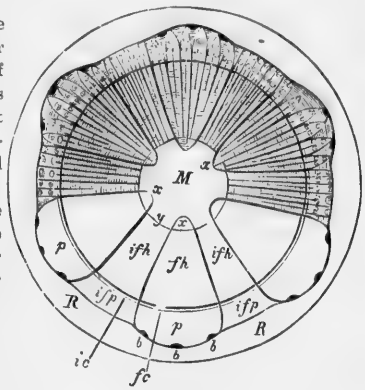


Fig. 280.

In monocotyledons, on the other hand, there is no cambium-layer, and consequently the bundle when once formed is incapable of further increase, and so is said to be *closed*. Fig. 281 is a representation of the cross-section of an endogenous stem in which many of these closed bundles are visible. Of course in such stems no bark is formed.

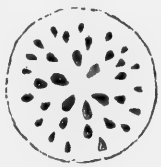


Fig. 281.

It has been explained that in the exogenous stem the xylem occupies one side of the fibro-vascular bundle, while the phloem occupies the other. In the closed bundles of

Ferns and Club-Mosses, as well as of some monocotyledons, however, a different arrangement prevails, the xylem occupying the central part of the bundle, and the phloem forming a circle around it. The former arrangement is described as *collateral*, while the latter is *concentric*. In many of the monocotyledons, as well as in the exogens, the bundles are collateral.

Fig. 282 shows a section of an exogenous stem somewhat older than that shown in Fig. 279. Here new bundles have been formed between the earlier ones, so that the whole centre of the stem, except the *pith* and the lines radiating from it, is occupied by the wood. This cylinder of wood is now encircled by a ring of cambium, beyond which are the tissues of the phloem.

The appearance presented by the cross-section of an exogenous stem is that of a series of concentric rings, each ring showing the limit of a year's growth. The portions of wood formed late in the summer are more compressed by the outlying tissue than those formed in spring, and hence the outer part of each year's ring appears denser, and is sharply marked off from the ring of the following year. No growth of the cambium takes place in the winter. The rays which intersect these rings as fine lines consist of portions of the ground or fundamental tissue which have been squeezed into their present form by the increasing fibro-vascular bundles on each side of them; they are called *medullary rays*, and, as the stem grows, new ones are formed from the cambium. Only the *primary* ones, however, extend from the pith to the bark; those formed later are shorter.

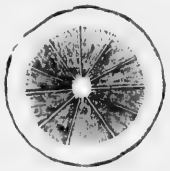


Fig. 282.

In roots a special arrangement of the tissues of the bundles prevails, the xylem and phloem forming alternate *rays*. This is the *radial* arrangement.

Fundamental or Ground-Tissue.

The Fundamental or Ground-Tissue comprises all the parts of the plant not already included in the epidermal and fibro-vascular systems. The collenchyma found just beneath the epidermis, sclerenchyma occurring in different parts, and laticiferous tissue are constituents of the fundamental system as well as the cork cells already referred to. In the monocotyledons ground-tissue in the form of parenchyma fills the space between the closed bundles of the stem; while in many plants in which fibro-vascular bundles are not produced, the ground-tissue constitutes the whole of the interior.

In exogenous stems the wood developed from the cambium is often different from that of the primary bundle as developed from the procambium. Pines, for example, have

vessels in the primary xylem, but none in the secondary, the latter being almost entirely made up of the cells with *bordered pits*, already described.

The bundles of the leaves are continuous with bundles in the stem. Leaves appear at first as protuberances on the side of the stem close to the growing point, and the [illegible] ends of the primary bundles almost at the ve[illegible] bend outwards towards the new leaves, the lower pa[illegible] being continued down the stem. In the monocotyledons these bundles first arch inwards towards the centre of the stem, and then outwards and downwards, thinning out as they descend. Hence, in a cross-section (Fig. 281) the bundles appear more crowded towards the circumference, and also smaller. Such a stem is, therefore, found to be harder at the outside than at the centre.

LABORATORY WORK WITH THE MICROSCOPE.

Practical Suggestions.

It is assumed that the teacher will give all necessary instructions as to the manipulation of the microscope, preservation and hardening of material, section-cutting and mounting, so that it will only be urged here that as the one object in view is to obtain a knowledge of plant-structure as exhibited in the living organism, the *simplest* methods are almost invariably the best. All the necessary section-cutting can be done with a good razor, and water will nearly always serve as a mounting medium, when fresh material is used.

The Cell. As a suitable object to begin with in the study of the vegetable cell, Professor Bower recommends the common *Spirogyra* which so frequently forms a green scum on the surface of ditches and slow-flowing waters. It is made up of unbranched threads irregularly matted together, and can generally be easily recognized. A small portion of the living plant should be mounted in water in the usual way, and studied first with a low power, when the following points can be observed and drawings made of them:

(a) The cell-wall which forms the lateral limit of each thread.

(b) The cross-walls which divide the threads into cells.

(c) The protoplasmic contents of each cell, with the green chlorophyll granules which here form spiral bands.

With a higher power try to make out:

(a) the film-like lining of each cell (*primordial utricle*).

(b) The large central cavity (*vacuole*) filled with colourless cell-sap.

(c) The green spirals imbedded in the lining of the cell.

(d) The nucleus, occupying a more or less central position in the cell.

(e) The threads of protoplasm connecting the nucleus with the lining of the cell.

Having observed these features in the living specimen try the effect of introducing a drop of iodine solution under the cover-glass. What is the effect upon the cell-wall? Upon the green spirals? Upon the nucleus? Try also the effect (upon freshly mounted specimens) of a weak (2½ per cent.) solution of common salt; of glycerine; of weak solution of potash.

All these observations may be repeated with any other simple vegetable forms, such as the prothallium of a fern, where the cells form a *surface* instead of a thread as in Spirogyra.

The *movements* of protoplasm may be easily observed in the root-hairs of aquatic plants, and in the stamen-hairs of *Tradescantia*.

THE BEAN AND THE MAIZE.

For practical work on the Bean and the Maize, seeds of these plants should be germinated in wet sawdust and the roots allowed to attain a length of several inches. Well-grown plants should also be available.

Root of Bean.

Make cross sections of the primary root a little back of the apex; clear in weak potash, and mount in glycerine. Note the following in order from the centre:

(a) The **Pith**, occupying the centre of the section.

(b) Several (usually four) groups of **primary xylem** [illegible]

(c) Alternate with, and somewhat exterior to these, the **phloem** groups.

(d) Filling the spaces between all the groups of (b) and (c), **parenchymatous tissue.**

(e) External to the xylem and phloem groups, a rather well marked belt of **pericambium** in a single layer, at least in that portion which is outside the phloem.

(f) External to the pericambium, a well marked single layer of cells, each with a characteristic *dark dot* on its radial walls. This layer constitutes the **bundle-sheath** (*endodermis*).

(g) External to (f), a thick band of many layers of cells, the **cortex**; and finally,

(h) a single superficial layer bearing hairs, the **epidermis.**

Make drawings of all the tissues observed.

Cut sections from older parts of the root, and compare with those already examined. Note the formation of *cambium* in the parenchyma internal to the phloem groups. To the division and growth of these cambium cells is due the *secondary* thickening of the root. Do the older sections exhibit epidermis? cortex?

If any of the sections pass through the origin of *lateral roots*, observe particularly how these originate. Are they formed on the surface of the main root, or do they arise from the deeper tissues? How is their position related to that of the primary xylem groups?

Root of Maize.

In making sections of the root of Maize, the directions already given for the Bean may be followed and a comparison instituted between corresponding sections. Note that there is much less difference between the roots of these plants than between their stems, so far as minute structure is concerned.

Apex of Root. Cut a longitudinal median section through the apex of a young root. Observe with a high power, and note the **root-cap**, a rather loose mass of parenchyma covering the tip. Note the boundary layer of cells on each side of the root; this is the **dermatogen**, or nascent epidermis. Enclosed by this is a tissue of many layers, the nascent cortex, and known as **periblem**. Within the periblem is the **plerome-cylinder**, from which the vascular ring of xylem and phloem bundles, observed in previous sections, is derived.

Make drawings of the tissues observed.

Stem of Bean.

In a cross-section of an internode of the stem make out the following parts, commencing at the centre:

(a) A central cavity (unless the stem is very young) caused by the tearing asunder of the central parenchyma as the outer parts of the stem enlarge.

(b) The parenchyma of the pith around the cavity.

(c) The **fibro-vascular bundles** arranged in a ring outside (b). Study the structure of a bundle, commencing at the narrow end next the centre, and observe in order:

(1) Comparatively large openings with thick walls. These are **vessels** of different kinds, the larger ones being *pitted* (as will be seen in a lon-

gitudinal section) and the smaller ones *spiral* and *annular*.

(2) Wedged in among the vessels, the much smaller thick-walled **wood-cells**. These vessels and wood-cells together constitute the xylem portion of the fibro-vascular bundle.

(3) A band of thin-walled, narrow and rather rectangular cells, in regular radial rows, the **cambium**.

(4) External to the cambium, the **bast**, consisting of many layers, the inner of thin-walled cells and made up of **sieve-tubes** and **bast-parenchyma**, and the outer of thick-walled cells constituting the **bast-fibres** or **sclerenchyma**. These elements external to the cambium constitute the phloem portion of the bundle.

(d) The **cortex**, a band of several layers of chlorophyll-bearing cells surrounding the ring of fibro-vascular bundles. The outer layers may show cell-walls strongly thickened in the angles, **collenchyma** (*subepidermis*).

(e) The **medullary rays**, bands of parenchyma separating the fibro-vascular bundles and connecting the pith with the cortex.

(f) The **epidermis**, a single layer of transparent cells forming the boundary of the stem.

Make drawings of tissues observed.

In a longitudinal radial section, follow the course of observation outlined above, noting all the tissues between the pith and the epidermis, and making drawings.

Compare a cross-section through a node with the cross-section already observed.

Stem of Maize.

In a cross-section of an internode of a well-grown stem, observe the following tissues, commencing at the outside:

(a) The **epidermis**, a single layer of cells.

(b) Immediately internal to (a) irregular groups of **sclerenchyma**.

(c) The **groundwork** of the section, consisting of thin-walled tissue (parenchyma) in which are imbedded

(d) The separate **fibro-vascular bundles**, smaller and more numerous towards the outside than towards the centre.

With a higher power, study the structure of a bundle and make out—

(1) Four large openings (*vessels*), the two very large ones being *pitted*, and of the other two the one

nearest the centre of the bundle *spiral*, the other *annular*.

(2) Around and between the two large vessels, thick-walled tissue consisting of **tracheids**.

(3) Below the pitted vessels and around the smaller vessels, thin-walled **parenchyma**. These three elements make up the xylem portion of the bundle.

(4) On the opposite side of the space separating the pitted vessels, a mass of **soft bast** (the phloem portion of the bundle).

(5) Surrounding all the above elements, a thick sheath of sclerenchyma.

Make a drawing of the bundle.

In longitudinal sections, make out all the above tissues, and draw them.

In longitudinal sections of the stems of both Bean and Maize, cut so as to pass through a node or insertion of a leaf, endeavour to trace the course of the vascular bundles, and to make out the relation of the bundles of the stem to those of the leaf.

Leaf of Bean.

A bit of leaf may be held in a slit in a piece of elder-pith, and thin sections made at right angles to the surface. Some of the sections may be immersed in alcohol for a time to drive out air, but as this process also dissolves the chlorophyll, other sections should be examined as cut. They may be mounted in water or dilute glycerine.

Note in order:

(a) The transparent upper layer, the **epidermis** the outer limit of which is the **cuticle.**

(b) Below this, rather long chlorophyll-bearing cells standing on end, the **palisade** tissue.

(c) Still lower, some irregular layers of chlorophyll-bearing cells, with intercellular spaces, the **spongy parenchyma.**

(d) The transparent lower layer, the **epidermis.**

(e) Possibly sections of veins. In these try to make out the elements of fibro-vascular bundles.

(f) Note the forms of hairs if any appear.

Make drawings of the sections.

Tear off with forceps a strip of epidermis, and mount as before. Note the absence of chlorophyll, and the very irregular outline of the cells. Find also examples of **stomata**, more especially in the lower epidermal layer. Observe if possible the **guard-cells**, and find out in what particular, if any, they differ from the other epidermal cells.

Leaf of Maize.

Make sections across the veins and midrib, and treat as above. Study the structure of the bundles of the veins and the midrib, and compare with those of the stem as already observed. Compare the parenchyma of the section with that of the Bean leaf.

Mount a bit of the epidermis, and compare the forms of the epidermal cells with those of corresponding cells in the Bean. Study the stomata. Do they occur on one or both surfaces?

Make drawings of the sections.

Calyx and Corolla.

If flowers of the Bean can be procured, sections of the calyx and corolla may be made in the same way as the ordinary leaf-sections. Determine if possible the cause of the colour, if any, of the petals. Compare the texture of the petal with that of the foliage-leaf. Are there stomata? vascular bundles?

Stamen.

It is very difficult to make sections of the anther of the Bean, because of its minuteness, but the structure of the anther of Marsh-Marigold may be readily observed, if sections of a young unopened flower are made. Note the two large lobes, each containing two cavities or pollen-sacs separated by a partition. In mature anthers these partitions are commonly broken down, so that each lobe then appears to be one-celled.

Is there a vascular bundle in the section?

Observe the pollen-grains, and if possible make out the origin of the grains by free-cell formation.

To observe the formation of pollen-tubes, make a **moist chamber** as follows: Cut a rough piece of cardboard the size of a slide, and make a hole in the centre somewhat smaller than a cover-glass. Soak the cardboard in water and place it on the slide. Make a weak solution of sugar (say 5 per cent.), and put a drop of it on the cover-glass. Place the pollen-grains in the drop and invert the cover-glass over the hole in the cardboard. Drying up can be prevented by occasionally wetting the cardboard. Put the slide away in a dark place for about 18 hours. At the end of this time pollen-tubes will probably be found in course of development, and may then be studied with a higher power.

Carpel.

A carpel of the Bean may be cut across and the structure of the wall compared with that of the foliage leaf.

It is difficult to make a satisfactory section of the ovule of the Bean, but by making a large number of transverse sections of an ovary of a young flower of Marsh-Marigold some good sections will be secured, which will show the essential parts. Note the two coats of the ovule, each of several layers of cells. Observe the **micropyle**, and within the coats the **nucellus**. In the latter is a large cell, the **embryo-sac**, which should be examined with a high power, in order to observe the central **nucleus**, the **ovum** with the two **synergidae**, near the micropylar end, and the **antipodal cells** at the opposite end.

Fertilization. The details of the process may be observed in flowers of Marsh-Marigold, Evening-Primrose, Veronica serpyllifolia, and others: sections made through the stigma will show the pollen-tubes penetrating the tissue, and an examination of the ovules will often show the tubes entering the micropyle.

The Seeds. As has been already pointed out the seed is characterized by the presence of the **embryo**, which is formed by cell-division in the embryo-sac, as a result of fertilization.

Seeds of Bean and grains of Maize should be soaked in water for a day or so and sections made in both cases. Observe the starch granules in sections of the cotyledon of the Bean and of the endosperm of Maize. Are the granules alike in both cases? Are there any other cell-contents?

ILLUSTRATIONS

OF

BEAN AND MAIZE.

ILLUSTRATIONS OF BEAN.

Fig. 283. Transverse section of root of Bean, taken a short distance behind the apex of the main root. The section passes through a lateral root. *tc*, trichomes; *ep*, epidermis; *pc*, parenchyma of cortex; *ed*, bundle-sheath (endodermis); *cb''*, pericambium; *ph*, phloem bundle; *xy'*, primary xylem bundle; *rc*, root-cap (of lateral root). (Howes.)

Fig. 284. Part of transverse section of the stem of Bean. *c*, cuticle; *ep*, epidermis; *ep'*, collenchyma; *pc*, parenchyma of cortex; *cb'*, cambium; *xy''*, xylem sclerenchyma; *xp*, xylem parenchyma; *xy'*, primary xylem; *pc'*, parenchyma of pith; *mr*, medullary ray; *xy,v*, xylem ray; *st*, sieve-tubes; *ph.r*, phloem rays; *p.p*, phloem parenchyma; *ph'*, hard bast (sclerenchyma). (Howes.)

Fig. 285. Radial longitudinal section of stem of Bean, corresponding to Fig. 284. Commencing at the left side, the elements shown are: cuticle, epidermis, collenchyma, parenchyma of cortex, hard bast, phloem parenchyma, soft bast (sieve-tubes), cambium, pitted vessels and xylem sclerenchyma, xylem parenchyma, annular and spiral vessels, pith parenchyma. (Howes.)

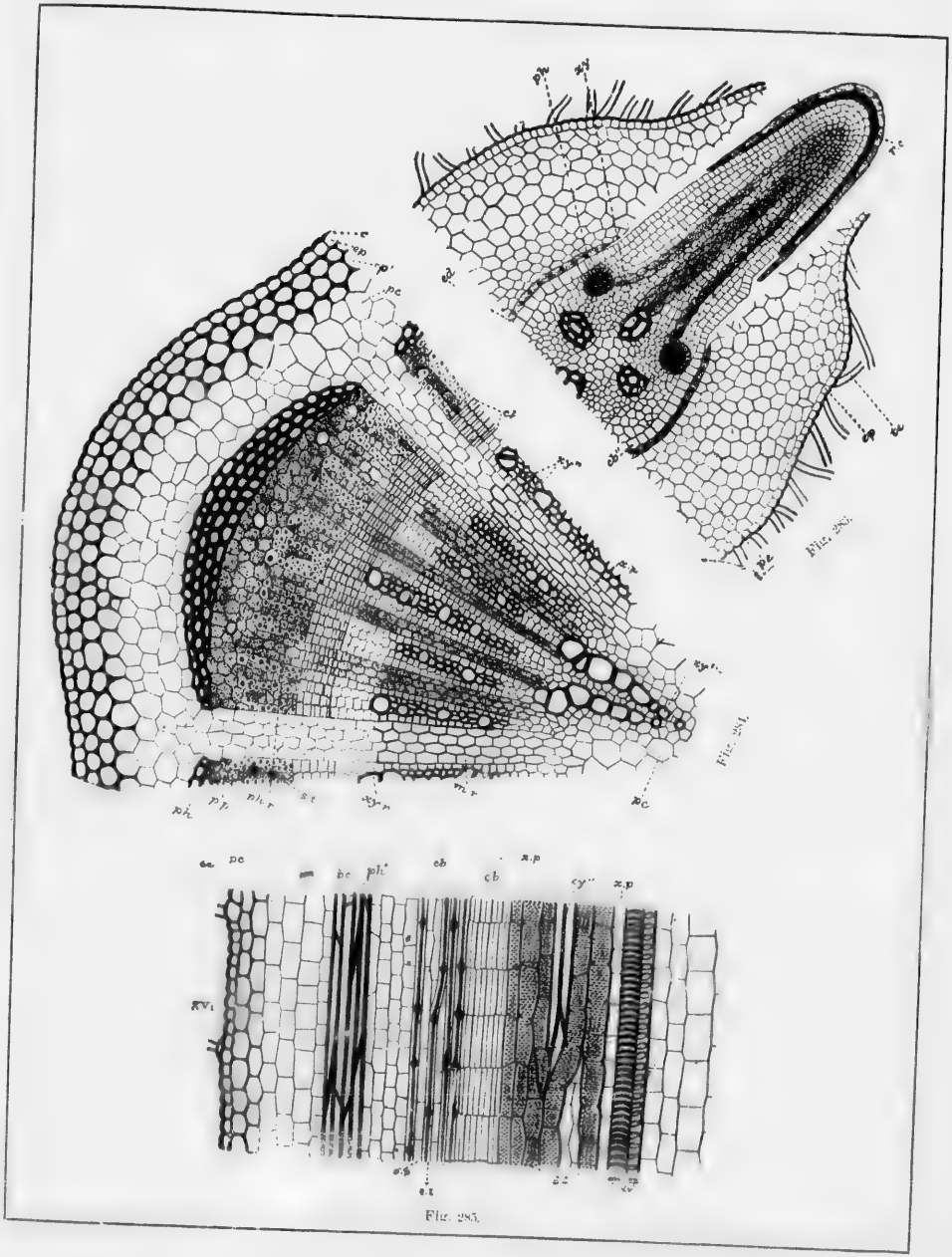


Fig. 285.

ILLUSTRATIONS OF MAIZE.

Fig. 286. Germination of Maize in successive stages. A and B, front and side views of embryo separately. In all parts of the figure *w* is the primary root; *ws*, the root-sheath; *w'*, *w''*, secondary roots; *e*, endosperm portion of seed; *sc*, cotyledon; *r*, open edges of same; *k*, the plumule; *b*, *b'*, *b''*, young leaves; *l*, part of the cast-off pericarp. (Sachs.)

Fig. 287. Longitudinal section of a grain of Maize. *c*, adherent pericarp; *fs*, base of fruit; *eg*, hard yellowish part of endosperm; *ew*, soft white part of endosperm; *sc*, cotyledon; *ss*, its apex; *e*, its epidermis; *k*, plumule; *w* (below), main root; *w* (above), secondary roots arising from the stem *st*; *ws*, root-sheath (the line connected with these letters should be longer). (Sachs.)

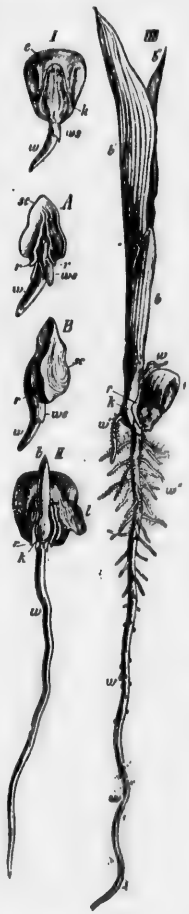
Fig. 288. Longitudinal section through apex of root of Maize. (A little more than half the width of the root is shown.) All within the line *vs* is the root proper; all below and outside this line is root-cap; *s*, apex of root; the first layer of cells within *v* is epidermis; *e*, its thickened outer wall; within the epidermis, several layers of cortex; *wfg*, belong to the plerome cylinder. (Sachs.)

Fig. 289. Protoplasm in cells of Maize. A, cells from a young leaf-sheath, showing numerous vacuoles separated by thin plates of protoplasm. B, cells from the first internode of the germinating plant. Here the protoplasm is broken up into rounded masses. *b*, vacuole; *k*, nucleus. (Sachs.)

Fig. 290. A, cell of endosperm of Maize. Thin plates of protoplasm separate the polygonal starch-grains. *a*—*g*, starch granules from germinating seed, in various stages of disintegration. (Sachs.)

Fig. 291. Cross-section of fibro-vascular bundle of Maize. *p*, parenchyma of ground-tissue; *a*, outer side. *i*, inner side of bundle; *g*, *g*, pitted vessels; *s*, spiral vessel; *r*, annular vessel; *l*, intercellular space filled with air; *v*, *v*, soft bast; the outer tissue of the bundle consists of thick-walled prosenchyma. (Sachs.)

Fig. 292. Cross-section of stem of Maize, showing parenchyma. *gw*, partition-wall of cellulose; *z*, intercellular spaces. (Sachs.)



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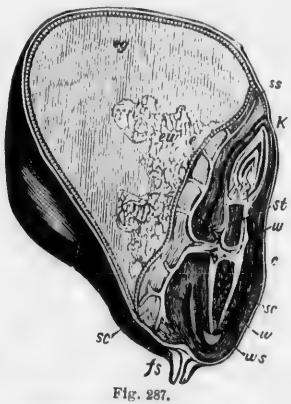

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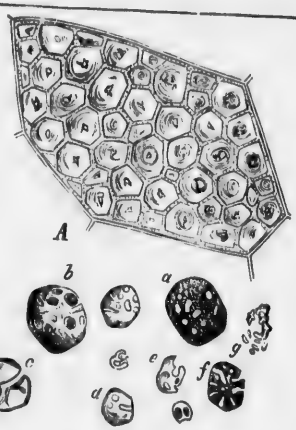

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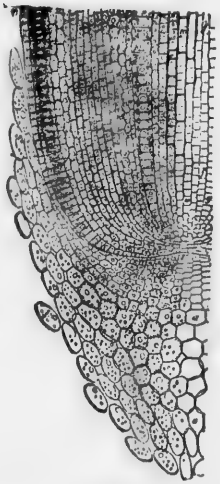
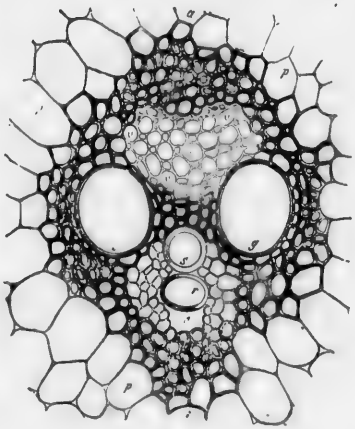


Fig. 288.



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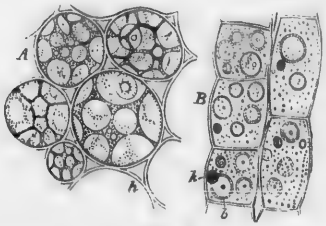

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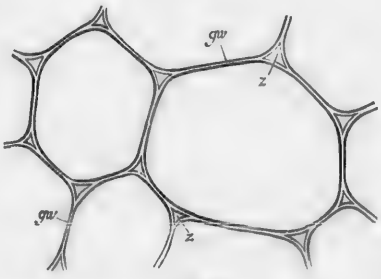

Fig. 292.

CRYPTOGAMOUS TYPES.

PTERIDOPHYTES.

Ferns.

Fig. 293 is a representation of our common Polypody. You may find it in almost any shaded rocky place. Running horizontally beneath the surface you will find the stem of the plant, which in this case is, therefore, a *rhizome*. A portion of the rhizome is shown in the lower part of the figure, with fibrous roots on the under side. From the upper side are developed the leaves, which, as you see, have long petioles, and if you find one which is still in the bud you will observe that it is rolled up lengthwise, as shown in Fig. 294. The vernation is, therefore, *circinate*, and this is the case in nearly all the Ferns. On examining the back of the leaf (Fig. 293 shows the back) we observe rows of brownish dots on each side of the middle veins of the upper lobes. Fig. 295 is an enlarged view, showing the position of these dots at the extremities of the veinlets. When we put one of these dots under the microscope it is seen to be a cluster of minute, stalked bodies, such as that shown in Fig. 296. These bodies are further found to be sacs filled with extremely fine dust, and the dust consists of multitudes of rounded particles all exactly alike. They are, in short, *spores*, and the sacs in which they are contained are the spore-cases, or *sporangia:* while the clusters of sporangia are the *fruit-dots*, or *sori*. Around each sporangium there is an elastic jointed ring which breaks at maturity, and by its elasticity ruptures the spore-case, which then discharges its spores, as shown in the figure. The leaf of the Fern, then, is something more than an ordinary foliage-leaf, and is known as the *frond*. The petiole is called the *stipe*, while the mid-rib is the *rhachis*.

A spore under certain conditions developes a slender thread-like cell which eventually gives rise to a thin, flat, green expansion, resembling that shown in Fig. 297. This is called the *prothallium*. From the under surface root-hairs are produced as shown in the figure. On the same surface, among the root-hairs, arise minute projections of tissue in which are developed cells corresponding to the pollen-grains of phanerogams. These projections are the *antheridia;* they contain cells in which are fertilizing bodies known as *antherozoids*. Also on the under surface of the prothallium, near the notch, we find structures analogous to the embryo-sac of the phanerogamous ovule. These are the *archegonia*. They are mostly flask-shaped

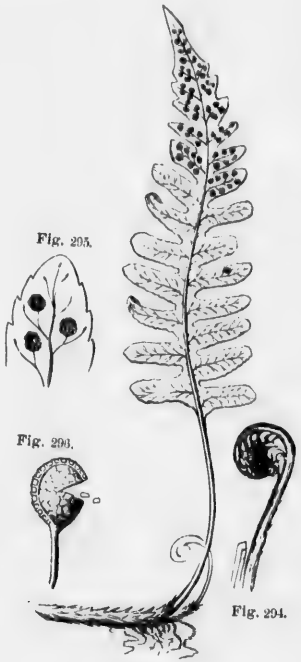

Fig. 295.

Fig. 296.

Fig. 294.

Fig. 293.

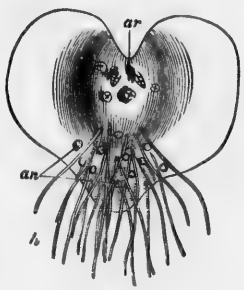

Fig. 297.

bodies, having a germ-cell—the *oosphere*—in the lower end. The antherozoids, on escaping from the antheridia, make their way down the necks of the archegonia, and coming in contact with the oospheres fertilize them. As a result of this fertilization, a plant is developed in all respects like the one which originally bore the spores on its fronds.

It is manifest, then, that we have here two distinct *generations*: first, the spore produces the prothallium which bears the antheridia and archegonia; secondly, the interaction of these gives rise to a plant which bears the spores. This phenomenon is spoken of as the *alternation of generations*.

The stems and roots of Ferns are found to contain vascular bundles which, like those of monocotyledons, are closed.

For a description of our common Ferns differing in detail from the Polypody, the student is referred to the Flora, page 169.

Horsetails.

Fig. 298 is a view of the fertile stem of *Equisetum arvense*, the Common Horsetail, of about the natural size. It may be observed early in spring almost anywhere in moist sandy or gravelly soil. It is of a pale brown colour and in place of leaves there is at each joint a sheath split into several teeth. At the summit of the stem is a sort of conical catkin, made up of a large number of six-sided bodies, each attached to the stem by a short pedicel. Each of these six-sided bodies turns out on examination to be made up of six or seven sporangia or spore-cases, which open down their inner margins to discharge their spores. Figs. 299 and 300 are enlarged outer and inner views of one of them. The spores themselves are of a similar nature to those of the Ferns, and reproduction is carried on in the same manner; but each spore of the Horsetail is furnished with four minute tentacles which closely envelope it when moist, and uncoil themselves when dry.

Fig. 298.

Fig. 300.

Fig. 299.

The fertile stems will have almost withered away by the time the sterile ones appear. These latter are of the same thickness as the fertile ones, but they are very much taller and are green in colour. Observe, also, the grooving of the sterile stem, and the whorls of 4-angled branches produced at the nodes.

The spores, upon germination, give rise to prothallia bearing antheridia and archegonia precisely as in the Ferns. The prothallium is usually small, flat, and irregularly branched or lobed, developing the antheridia at the projecting ends of the lobes, and the archegonia in the angles between

them; or, in other cases, the prothallia may be dioecious. Fertilization of the germ-cell, which occupies a cavity at the base of the archegonium, takes place exactly as in the Ferns, and, as a result of fertilization, the germ-cell developes into a spore-bearing plant similar to the original one. Here, therefore, we have again exhibited an alternation of generations.

Other species of Equisetum of common occurrence, instead of producing a special fertile branch, develope sporangia at the extremities of the ordinary leafy stems.

These plants, like the Ferns, exhibit fibro-vascular bundles, and the epidermis is specially characterized by the excessive amount of silica contained in it, some of the species being used for scouring and polishing by reason of this property.

The curious *elaters* (Fig. 301) attached to the spores doubtless assist them to escape from the spore-cases, and subsequently aid in dispersing them.

Fig. 301

Club-Mosses.

Fig. 302 is a representation of a branch of *Lycopodium clavatum*, one of our common Club-Mosses. The creeping stem lies flat upon the ground, and often attains a great length, sending up at intervals erect branches with crowded linear-awl-shaped leaves, some of which, like the one shown in the figure, are terminated by a slender peduncle bearing one or more cylindrical spikes. These are the fertile branches, and the leaves upon them, or at all events upon the slender upper part, are very much smaller than upon the ordinary sterile branches.

Fig. 302.

It is to be observed that the stems and roots of these plants branch *dichotomously*.

The sporangia are produced in the axils of the leaves of the terminal spike. One of these leaves greatly magnified, with its attached sporangium, is shown in Fig. 303. The sporanginm opens by a slit at the top to discharge the spores.

Fig. 303.

It is only quite recently that the prothallium has been detected. It is described in the case observed as a "yellowish-white irregular lobed body, sparingly furnished on its under surface with small root-hairs." The antheridia and archegonia appear to be produced on the upper surface, and these by their interaction, give rise to the new plant which bears the spores, just as in the Ferns and Horsetails; so that again there is an alternation of generations.

It is a fact of great interest that in some plants nearly related to the Club-Mosses, *two kinds* of spores—large and small—are produced in separate sporangia. The large ones

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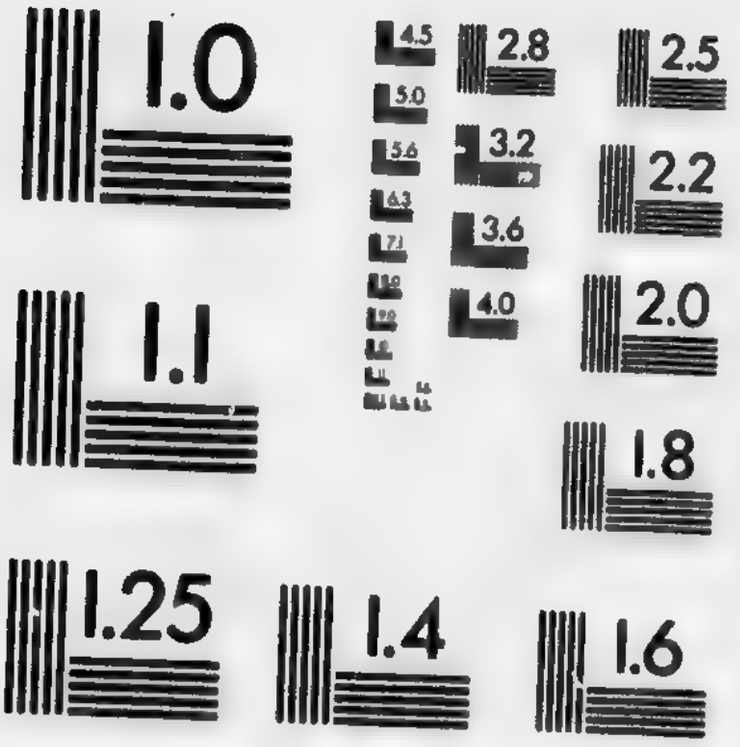

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develope prothallia upon which archegonia are formed, and the smaller others upon which antheridia appear.

The three plants just considered, while evidently differing in certain details of structure and in general aspect, nevertheless have a number of characters in common:

1. *They agree in their mode of reproduction, which is by spores, these bodies being quite unlike the* SEEDS *with which we are now familiar, and which, you will recollect, always contain the embryo of the new plant.*
2. *They all exhibit an alternation of generations.*
3. *They all have true roots.*
4. *The three tissue-systems—the epidermal, the fibro-vascular, and the fundamental—though not all developed to so high a degree as in the Phanerogams, still can be very clearly made out in both roots and stems. The fibro-vascular bundles are always closed, as in monocotyledons, and are, as a general rule, concentric.*

Plants with these common characteristics constitute a group called Pteridophytes or Vascular Cryptogams, "cryptogam" being a general term applicable to all plants which do not produce true flowers, as "phanerogam" applies to all those which do.

BRYOPHYTES.

Mosses.

Fig. 304 is a representation of the common Hair-Moss (*Polytrichum commune*), which may be found in early summer almost anywhere. It grows in dense masses, and upon examination it will be found that while many of the stems resemble that shown in Fig. 304, the upper extremities of the others form rosettes, as in Fig. 305, whilst others again terminate in ordinary vegetative buds.

Fig. 304.

Let us first examine a specimen as represented in Fig. 304. There is, it will be observed, a well-marked stem, or leaf-bearing axis, upon which the crowded minute leaves are sessile. In the Mosses they always are so, and they are found, upon examination with a good microscope, to consist as a rule of only one layer of cells, being therefore much simpler in construction than those of the plants we have so far been engaged upon. It is also to be noticed that the leaves of Mosses are without stomata.

Fig. 305.

Observe now that our Moss has no true roots. It is, however, fixed to the soil upon which it grows by numerous root-hairs or *rhizoids*.

The slender scape-like stalk which rises above the leaves is technically called the *seta* or bristle; in the left-hand part of the figure (c) the upper end of the seta is covered by a

hairy cap, the *calyptra*. In the right-hand portion the calyptra has been removed, disclosing a little pod, variously spoken of as the *theca*, or *urn*, or *capsule*, or *sporangium*. Fig. 306 is an enlarged view. This capsule is closed at the top by a circular lid, the *operculum*, which falls away when the capsule is mature, thus allowing the escape of the *spores*, which are produced in it. The spores are developed upon the surface of a central column which rises from the bottom of the capsule, and which is known as the *columella*. The opening through which the spores escape is called the *stoma*, and a good lens reveals the fact that around the stoma there is a circle (sometimes two) of minute teeth, known collectively as the *peristome*. In the Moss now before us the peristome consists of sixty-four teeth. In other Mosses the number varies, being always, however, some power of 2; either 4, or 8, or 16, or 32, or 64. Occasionally the teeth are altogether absent.

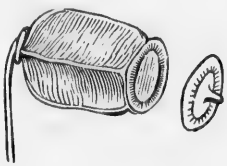


Fig. 306.

We shall now consider the mode of reproduction in the Mosses. Let us commence with the spore. This, upon meeting with proper conditions, bursts its outer coat (the *exospore*), and the inner coat (the *endospore*) is then protruded as a slender tube. This continues to grow by repeated divisions, until at length, in most cases, a tangled thread-like mass of vegetation is produced, to which the name *protonema* has been given. After the lapse of several days minute buds are developed at different points upon the protonema, and these are found to consist of whorls of scaly leaves. This is the beginning of the development of the ordinary Moss-plant. Upon the plants thus arising from the buds are developed antheridia and archegonia, the former in the axils of the leaves forming the rosettes shown in Fig. 305, and the latter at the apex of other stems, as shown in Fig. 304. The antheridia are seen under the microscope to be club-shaped bodies, containing a mass of cells in which the antherozoids are formed. Fig. 307 shows an antheridium (*A*) with escaping antherozoids *a*. At (*B*) is seen a sperm-cell with contained antherozoid. At *c* is the antherozoid set free. The archegonia are flask-shaped bodies, with a lower expanded portion and a long neck above. Fig. 308 shows the apex of a fertile stem with several archegoniain the centre, and Fig. 309 shows a single archegonium very highly magnified. The antherozoids upon being set free make their way down the necks of the archegonia and unite their substance with that of special cells in the lower end (one in each archegonium). These cells, as a consequence of being thus fertilized, become surrounded by a thin coat and immediately begin

Fig. 307.

to grow upwards, developing the slender stalks (setæ) with the capsules at the summit, and surrounded by the calyptra, which is, in fact, nothing but the wall of the archegonium which is torn away at its base and carried upwards. Then the spores are developed around the columella, and the round of life of the plant is completed.

As in the Ferns, we have here also exhibited an alternation of generations, the one generation being that arising from the development of the spore and resulting in the production of the antheridia and archegonia; the other being that arising from the fertilization of the special cells in the archegonia, and resulting in the production of spores.

Liverworts.

Figs. 310 and 311 are representations of portions of a very common Liverwort, *Marchantia polymorpha*. It may be found growing along the borders of marshes and in wet places generally, often with intermingled moss. It is of a deep green colour, and usually spreads over a considerable extent of surface. There is no appearance of leaves, the plant-body lying flat upon the surface upon which it grows, and putting forth root-hairs on the under side. From the upper side arise peculiar stalked bodies of two sorts, as shown in the figures; the one consisting of flattened or slightly convex disks, and the other being star-shaped. These stalked bodies contain the reproductive organs. In cavities on the upper surface of the flattened disks are produced the antheridia, from the cells of which are liberated the antherozoids. On the under surface of the rays of the star-shaped bodies are produced clusters of flask-shaped archegonia, each with a germ-cell at its base, and fertilization takes place in the manner already described in the account of the Moss. As a result of fertilization, a capsule is developed which produces spores, pretty much as in the Mosses, the stalk in *Marchantia* the stalk of the capsule is very short and the whole is surrounded by a loose sheath which grows up from the base and at length completely encloses it. The spores on germinating develope into plant bodies such as we have described, so that the alternation of generations is here also well marked.

Other Liverworts more nearly resemble the Mosses in form, having leafy stems, from the summit of which arise slender stalks with capsules at the upper end. These capsules, however, do not open by a stoma, but are four-valved, and at maturity the valves split asunder, allowing the escape of the spores. In the leaves of these latter forms there are no veins of any kind. Forms in which the plant-body is a flat expansion, as in *Marchantia*, are

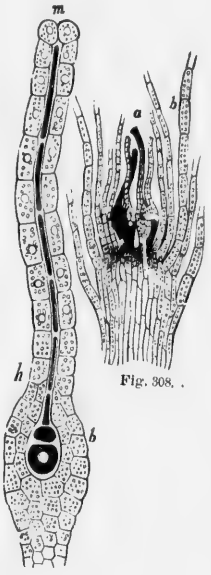


Fig. 308.

Fig. 309.

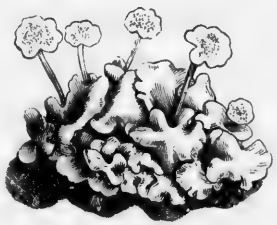


Fig. 310.

distinguished as *thalloid*, while the leafy forms are said to be *foliose*.

It remains to be added that *Marchantia* and other Liverworts reproduce themselves by buds as well as by spores. These buds (*gemmæ*) are found in little cup-shaped receptacles which appear on the surface of the plant-body. They consist of simple masses of tissue which fall away when fully grown, and immediately develope into new plants.

The Mosses and Liverworts constitute a distinct group of plants called Bryophytes. It will be evident from the preceding descriptions that in the matter of reproduction they do not differ materially from the Pteridophytes. They are, however, distinctly separated from them by the *simpler organization of their tissues*. The Bryophytes have no true roots, but only root-hairs or rhizoids. The whole plant body is, as a rule, composed of thin-walled parenchyma, and only in a few cases is there any appearance of a development of a fibro-vascular system, and that only of the vaguest possible kind. There is, however, a well-defined epidermal system, and stomata are not uncommon.

Fig. 311.

THALLOPHYTES.

Mushroom.

Fig. 312 is a representation of the Common Mushroom of the natural size, while Fig. 313 shows the several stages of its growth. At *A* is seen a matted fibrous mass, which is the underground portion of the plant. It is called the *mycelium;* at several places on it rounded outgrowths of different sizes are visible. These eventually develope into the overground part of the Mushroom. At *II* is shown a vertical section through one of these outgrowths at an early stage; at *l* in this figure you will observe two dark dots; these are the open ends of a channel which forms a complete ring in the interior. At *III* they are much more distinct, and here is also manifest a difference between the upper and lower sections, which is still more marked at *IV* and *V*. The upper spreading portion is called the *pileus;* at *V* the lower edge of the pileus is still attached by a circular membrane to the stalk. In this stage the membrane is called the *veil;* later on, as seen in Fig. 312, it is torn away from the pileus and now forms the *annulus*, or ring, about the stalk. Upon the under side of the pileus are produced a great many vertical, thin plates, called *lamellæ* or *gills*. If we make a vertical section through the pileus so as to cut across a number of the lamellæ, they will present the appearance shown at

Fig. 312.

A, Fig. 314, and if we magnify one of these cross-sections it will appear as at *B*, where there is seen an outer layer of cells standing on end. The whole of both surfaces of the lamellæ is covered with such cells, and this special layer is the *hymenium*. At *C*, the left-hand portion of the figure shows a number of these cells much more highly magnified, some of them narrowed in at the top so as to form slender points, upon each of which is a rounded body. These rounded bodies are the *spores;* the narrowed ends of the cells are called *sterigmata*, and the projecting cells which bear them are specially known as *basidia*. The spores are formed by the simple narrowing in of the outer ends of the basidia.

The mycelium is, therefore, the vegetative part of the Mushroom while the stalked pileus above the surface is the fructification. The mycelium is developed directly from the spore, but so far there have not been discovered any indications of the interaction of sperm-cells and germ-cells such as characterize the Bryophytes and Pteridophytes.

You will note the entire absence of green colouring-matter. The Mushrooms produce no chlorophyll, and, consequently, are incapable of assimilation. They are always found growing upon decaying organic matter, as the leaf-soil of forests and meadows, etc.

The Mushrooms are representatives of a large class of plants called **Fungi,** all the members of which are destitute of chlorophyll. The cells of which they are made up are generally in rows so as to form long threads which are known as *hyphæ*, and these may be either loosely interwoven, as in ordinary Moulds, or firmly compacted together, as in the Mushroom.

As just mentioned, Mushrooms are saprophytic in their habits; but there are also Fungi which are parasitic, such as Rust and Smut. To the Fungi belong such organisms as the Yeast-plant, and the Bacteria which are found in putrefying matter, and are the cause of, or are associated with, diseases of various kinds.

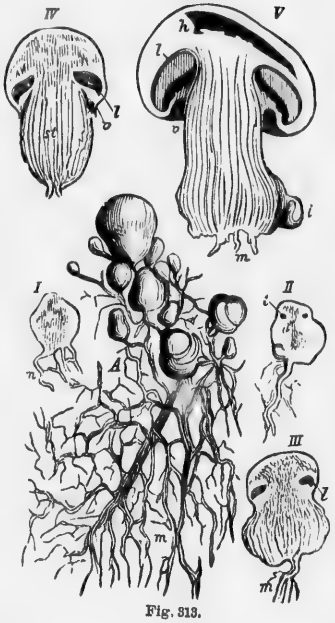


Fig. 313.

Lichens.

These plants may be found growing on the bark of trees, on old fences, on rocks, or on the ground. They differ widely in external appearance, sometimes growing erect and imitating a stem and branches, as in Fig. 315; sometimes forming flat expansions which adhere to the surface upon which they grow, as in Fig. 316. Some species are yellow, others red, others grey. A very common one is that represented in Fig. 316. It may be found on many tree trunks, and will be easily recognized by the yellow disks which dot its surface.

The flat part of the Lichen is the thallus, or vegetative portion, while the yellow, cup-shaped disks (the *apothecia*) contain the fructification. Fig. 317 shows a section of the apothecium, and also the lobing of the margin of the thallus. Fig. 318 is a very highly magnified view of a section of a thallus, showing it to be largely made up of cells, or *hyphæ*, similar to those of the Mushroom. But in the Lichen there are visible, in addition, large numbers of spherical *green* cells (*g g* in the figure) known as *gonidia*, which either occupy well-marked layers, as in the present instance, or are scattered through the body of the thallus. The presence of the gonidia may be said to be the distinguishing feature of the Lichens. Their true relation and function were for a long time doubtful, widely different opinions being held, but it is now generally admitted that the gonidia are themselves *chlorophyll-bearing plants*, and that the remainder of the Lichen is a true Fungus, *parasitic upon the gonidia*.

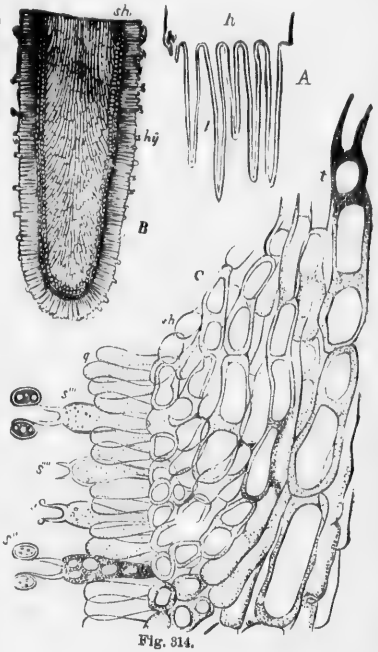


Fig. 314.

The structure of the apothecium is very well shown in Fig. 319. From the hyphæ are developed large, club-shaped, vertical cells (the *asci*) which penetrate between the narrower vertical branches of the hyphæ (the *paraphyses*). In the asci arise the spores (technically *ascospores*), usually eight in each, and these when mature are discharged from the asci, and give rise to new plants. The ascospores are formed in the asci by the process known as *free cell-formation*. The protoplasm in the asci collects about as many different points as there are spores to be formed, and a wall is then secreted about each. This mode, which is characteristic of a large number of Fungi, is quite distinct from that which prevails in the Mushrooms, where, as we have seen, the spores are formed by *abstriction*.

Chara.

Fig. 320 represents a Chara of the natural size. It grows almost anywhere in fresh waters, and is quite readily distinguished from other thread-like aquatics by the whorls of so-called leaves which encircle the stem, and also by the general gritty nature of the plant. A very offensive odour is emitted by the plant in course of decay. Its green colour shows at once the presence of chlorophyll. On the branches you may observe hundreds of minute, more or less rounded, bodies; Fig. 321 is an enlarged view of one of them. Here, at *b*, is shown a large central nucleus (the *nucule*) enclosed in a spiral covering. This spiral consists of five long cells side by side, all of which wind about the central body, and have

Fig. 315.

Fig. 316.

their ends projecting above it. The nucule is a row of cells of which the highest is the germ-cell, and the whole answers, in fact, to the archegonium of the Bryophytes and Pteridophytes. It is in this plant called the *carpogonium*. Just below it is a globular body made up of eight triangular shield-shaped segments arranged about a central cavity. From the inner end of each segment several coiled filaments, of many cells each, project into the cavity. At maturity the shields separate, and the filaments eventually break up into their constituent cells, each of which then liberates an antherozoid. The antherozoids make their way down the necks of the carpogonia and fertilize the germ-cells. The spiral cells then harden, and form a firm coat for the spore within. As the plant decays in the autumn, these seed-like sporocarps, as they are now called, drop off and fall to the bottom of the water, where they eventually germinate. On germination, they first produce a simple form to which the name *pro-embryo* has been given, and from which arises the plant-body which bears the antheridia and carpogonia.

There is, therefore, displayed in this case an alternation of generations.

Chara belongs to a group of plants known as **Algæ**. They grow either in the water or upon damp surfaces. They differ from the Fungi principally in developing chlorophyll, so that they are able to assimilate. In colour, the Algæ are often green, but in other cases the chlorophyll is obscured by the presence of other colours, such as brown and red. In the lowest forms of both Algæ and Fungi reproduction takes place by simple division of the cells. In higher forms the entire contents of two similar adjacent cells coalesce to form a new one, from which the new plant springs. This is the process of conjugation. In still higher forms, as in Chara, reproduction takes place by fertilization.

The Algæ, Fungi, and Lichens together constitute a great group called **Thallophytes**.

Fig. 317

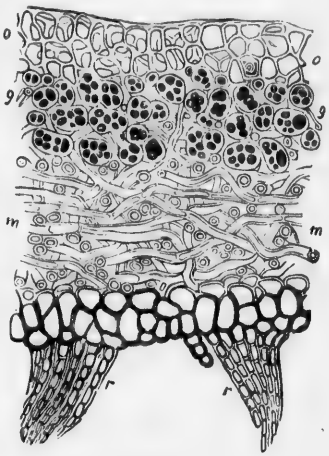


Fig. 318.

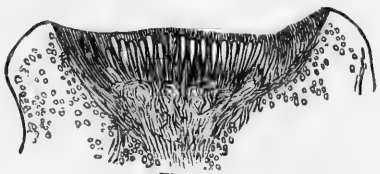


Fig. 319.

Fig. 320.

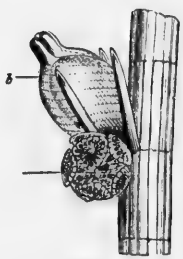


Fig. 321.

KEY TO THE FAMILIES OR ORDERS.

SERIES I. PHANEROGAMS.

Plants producing true flowers and seeds.

CLASS I. DICOTYLEDONS.

Distinguished ordinarily by having net-veined leaves, and the parts of the flowers in fours or fives, very rarely in sixes. Wood growing in rings, and surrounded by a true bark. Cotyledons of the embryo mostly two.

SUB-CLASS I. ANGIOSPERMS.

Seeds enclosed in an ovary.

I. POLYPETALOUS DIVISION.

Two distinct sets of Floral Envelopes. Parts of the corolla separate from each other.

A. Stamens more than twice as many as the petals.

* *Stamens hypogynous (inserted on the receptacle).*

+ *Pistil apocarpous (carpels separate from each other).*

RANUNCULACEÆ.—Herbs. Leaves generally decompound or much dissected 2

ANONACEÆ.—Small trees. Leaves entire. Petals 6, in 2 sets 7

MAGNOLIACEÆ—Trees. Leaves truncate. Fruit resembling a cone 6

MENISPERMACEÆ.—Woody twiners. Flowers dicecious. Leaves peltate near the edge 7

Brasenia, in

NYMPHÆACEÆ.—Aquatic. Leaves oval, peltate; the petiole attached to the centre 9

MALVACEÆ.—Stamens monadelphous. Calyx persistent. Ovaries in a ring 24

Podophyllum, in

BERBERIDACEÆ.—Calyx fugacious. Leaves large, peltate, deeply lobed. Fruit a large fleshy berry, 1-celled 8

++ *Pistil syncarpous. (Stigmas, styles, placentæ, or cells, more than one.)*

Actæa, in

RANUNCULACEÆ, might be looked for here. Fruit a many seeded berry. Leaves compound 2

NYMPHÆACEÆ.—Aquatics. Leaves floating, large, deeply cordate 9

SARRACENIACEÆ.—Bog-plants. Leaves pitcher-shaped 10

PAPAVERACEÆ.—Juice red or yellow. Sepals 2, caducous 10

CAPPARIDACEÆ.—Corolla cruciform, but pod 1-celled. Leaves of 3 leaflets 16

HYPERICACEÆ.—Leaves transparent-dotted. Stamens usually in 3, but sometimes 5, clusters .. 19

CISTACEÆ.—Sepals 5, very unequal, or only 3. Ovary 1 celled, with 3 parietal placentæ 18

MALVACEÆ.—Stamens monadelphous, connected with the bottom of the petals. Calyx persistent. Ovaries in a ring 24

TILIACEÆ.—Trees. Flowers yellowish, in small hanging cymes, the peduncle with a leaf-like bract attached 25

* * *Stamens perigynous (inserted on the calyx).*

Portulaca, in

PORTULACACEÆ.—Low herbs, with fleshy leaves. Sepals 2, adhering to the ovary beneath. Pod opening by a lid 23

ROSACEÆ.—Leaves alternate, with stipules. Fruit apocarpous, or a drupe, or a pome 38

* * * *Stamens epigynous (attached to the ovary).*

Nymphæa, in

NYMPHÆACEÆ. — Aquatic. Leaves floating. Flowers white, large, with numerous petals gradually passing into stamens 9

B. Stamens not more than twice as many as the petals.

* *Stamens just as many as the petals, and one stamen in front of each petal.*

BERBERIDACEÆ.—Herbs (with us). Anthers opening by uplifting valves 8

PORTULACACEÆ.—Sepals 2. Styles 3-cleft. Leaves 2, fleshy 23

VITACEÆ.—Shrubs, climbing by tendrils. Calyx minute 29

RHAMNACEÆ.—Shrubs, not climbing 29

Lysimachia, in

PRIMULACEÆ, is occasionally polypetalous. Flowers yellow, in axillary spikes; the petals sprinkled with purplish dots 91

* * *Stamens either just as many as the petals and alternate with them, or not exactly the same number.*

+ *Corolla irregular.*

FUMARIACEÆ.—Corolla flattened and closed. Stamens 6 11

VIOLACEÆ.—Corolla 1-spurred. Stamens 5. Pod with 3 rows of seeds on the walls..... 17

BALSAMINACEÆ.—Corolla 1-spurred, the spur with a tail. Stamens 5. Pod bursting elastically. 27

POLYGALACEÆ.—Lower petal keel-shaped, usually fringed at the top. Anthers 6 or 8, 1-celled, opening at the top. Pod 2-celled..... 32

LEGUMINOSÆ. — Corolla mostly papilionaceous. Filaments often united. Ovary simple, with one parietal placenta. Leaves compound.... 33

++ Corolla regular, or nearly so.

1. Calyx superior (*i.e.*, adherent to the ovary, wholly or partially).

(a) Stamens perigynous (inserted on the calyx).

Cratægus, in

ROSACEÆ.—Shrubs. Stamens occasionally from 5 to 10 only. Leaves alternate, with stipules. Fruit drupe-like, containing 1–5 bony nutlets. 38

SAXIFRAGACEÆ. —Leaves opposite or alternate, without stipules. Styles or stigmas 2; in one instance 4. Ovary 1-celled, with 2 or 3 parietal placentæ..... 46

HAMAMELACEÆ.—Shrubs. Stamens 8; styles 2. Flowers yellow, in autumn..... 48

HALORAGEÆ.—Aquatics. Stamens 4 or 8. Styles or sessile stigmas 4..... 49

ONAGRACEÆ.—Flowers symmetrical. Stamens 2, 4, or 8. Stigmas 2 or 4, or capitate..... 49

MELASTOMACEÆ.—Anthers 1-celled, opening by a pore at the apex. Stamens 8. Style and stigma 1 Flowers purple..... 51

LYTHRACEÆ.—Calyx apparently adherent to, but really free from, the ovary. Stamens 10, in 2 sets. Leaves mostly whorled..... 51

CUCURBITACEÆ.—Tendril-bearing herbs. Flowers monœcious..... 52

(b) Stamens epigynous (on the ovary, or on a disk which covers the ovary).

Euonymus, in

CELASTRACEÆ.—Shrub, with 4-sided branchlets, not climbing. Leaves simple. Pods crimson when ripe. Calyx not minute..... 30

UMBELLIFERÆ. — Flowers chiefly in compound umbels. Calyx very minute. Stamens 5. Styles 2. Fruit dry, 2-seeded..... 53

ARALIACEÆ.—Umbels not compound, but sometimes panicled. Stamens 5. Styles usually more than 2. Fruit berry-like..... 56

CORNACEÆ.—Flowers in cymes or heads. Stamens 4. Style 1..... 57

2. Calyx inferior (*i.e.*, free from the ovary).

(a) Stamens hypogynous (on the receptacle).

CRUCIFERÆ.—Petals 4. Stamens 6, tetradynamous. Pod 2-celled..... 12

CISTACEÆ.—Petals 3. Sepals 5, very unequal; or only 3. Pod partly 3-celled..... 18

DROSERACEÆ.—Leaves radical, beset with reddish glandular hairs. Flowers in a 1-sided raceme 19

Elodes, in

HYPERICACEÆ. — Leaves with transparent dots. Stamens 9, in 3 clusters..... 19

CARYOPHYLLACEÆ.—Styles 2–5. Ovules in the centre or bottom of the cell. Stem usually swollen at the joints. Leaves opposite..... 21

LINACEÆ.—Stamens 5, united below. Pod 10-celled, 10-seeded..... 25

GERANIACEÆ.—Stamens 5. Carpels 5,—they and the lower parts of the 5 styles attached to a long beak, and curling upwards in fruit..... 26

OXALIDACEÆ.—Stamens 10. Pod 5-celled. Styles 5, distinct. Leaflets 3, obcordate, drooping at night-fall..... 27

ERICACEÆ.—Anthers opening by pores at the top, or across the top. Leaves mostly evergreen, sometimes brown beneath; but in some instances the plant is white or tawny..... 85

(b) Stamens perigynous (plainly attached to the calyx).

SAXIFRAGACEÆ.—Leaves opposite or alternate, without stipules. Styles or stigmas 2; in one instance 4. Carpels fewer than the petals... 46

CRASSULACEÆ.—Flowers *symmetrical*. Stamens 10 or 8. Leaves sometimes fleshy..... 48

LYTHRACEÆ.—Stamens 10, in two sets. Calyx enclosing, but really free from, the ovary. Leaves mostly whorled..... 51

(c) Stamens attached to a fleshy disk in the bottom of the calyx-tube.

ANACARDIACEÆ.—Trees, or shrubs, not prickly. Leaves compound. Stigmas 3. Fruit a 1-seeded drupelet..... 28

CELASTRACEÆ.—Twining shrub. Leaves simple. Pods orange when ripe..... 30

SAPINDACEÆ.—Shrubs, or trees. Fruit 2-winged, and leaves palmately-veined. *Or*, Fruit an inflated 3-celled pod, and leaves of 3 leaflets. Styles 2 or 3..... 31

(d) Stamens attached to the petals at their very base.

Claytonia, in

PORTULACACEÆ.—Sepals 2. Leaves fleshy. Style 3-cleft..... 23

AQUIFOLIACEÆ. — Shrubs, with small axillary flowers, having the parts in fours or sixes. Fruit a red berry-like drupe. Stigma sessile. Calyx minute..... 90

II. GAMOPETALOUS DIVISION.

Corolla with the petals united together, in however slight a degree.

A. Calyx superior (adherent to the ovary).

** Stamens united by their anthers.*

CUCURBITACEÆ.—Tendril-bearing herbs 52

COMPOSITÆ.—Flowers in heads, surrounded by an involucre 64

LOBELIACEÆ.—Flowers not in heads. Corolla split down one side 83

** * Stamens not united together in any way.*

+ Stamens inserted on the corolla.

DIPSACEÆ.—Flowers in heads, surrounded by an involucre. Plant prickly 63

VALERIANACEÆ.—Flowers white, in clustered cymes. Stamens fewer than the lobes of the corolla 63

RUBIACEÆ.—Leaves, when opposite, with stipules; when whorled, without stipules. Flowers, if in heads, without an involucre 61

CAPRIFOLIACEÆ.—Leaves opposite, without stipules; but, in one genus, with appendages resembling stipules 58

+ + Stamens not inserted on the corolla.

CAMPANULACEÆ.—Herbs with milky juice. Stamens as many as the lobes of the corolla 63

ERICACEÆ.—Chiefly shrubby plants or parasites. Stamens twice as many as the lobes of the corolla 85

B. Calyx inferior (free from the ovary).

** Stamens more than the lobes of the corolla.*

LEGUMINOSÆ.—Ovary 1-celled, with 1 parietal placenta. Stamens mostly diadelphous 33

Adlumia, in

FUMARIACEÆ.—Plant climbing. Corolla 2-spurred. 11

MALVACEÆ.—Filaments monadelphous. Carpels in a ring 24

ERICACEÆ.—Chiefly shrubby plants, with simple entire leaves. Stamens twice as many as the lobes of the corolla 85

POLYGALACEÆ.—Anthers 6 or 8, 1-celled, opening at the top. Pod 2-celled. Flowers irregular; lower petal keel-shaped, and usually fringed at the top 32

OXALIDACEÆ.—Stamens 10, 5 of them longer. Styles 5, distinct. Leaflets 3, obcordate, drooping at night-fall 27

** * Stamens just as many as the lobes of the corolla, one in front of each lobe.*

PRIMULACEÆ.—Stamens on the corolla. Ovary 1-celled, with a free central placenta rising from the base 91

** * * Stamens just as many as the lobes of the corolla, inserted on its tube alternately with its lobes.*

+ Ovaries 2, separate.

APOCYNACEÆ.—Plants with milky juice. Anthers converging round the stigmas, but not adherent to them. Filaments distinct 114

ASCLEPIADACEÆ.—Plants with milky juice. Anthers adhering to the stigmas. Filaments monadelphous. Flowers in umbels 114

+ + Ovary 4-lobed around the base of the style.

Mentha, in

LABIATÆ.—Stamens 4. Leaves opposite, aromatic 100

BORRAGINACEÆ.—Stamens 5. Leaves alternate ... 105

+ + + Ovary 1-celled; the seeds on the walls.

HYDROPHYLLACEÆ.—Stamens 5, usually exserted. Style 2-cleft. Leaves lobed and sometimes cut-toothed 108

GENTIANACEÆ.—Leaves entire and opposite; or (in Menyanthes) of 3 leaflets 112

+ + + + + Ovary with 2 or more cells.

AQUIFOLIACEÆ.—Shrubs. Corolla almost polypetalous. Calyx minute. Fruit a red berry-like drupe. Parts of the flower chiefly in fours or sixes 90

PLANTAGINACEÆ.—Stamens 4. Pod 2-celled. Flowers in a close spike 91

Verbascum, in

SCROPHULARIACEÆ.—Corolla nearly regular. Flowers in a long terminal spike. Stamens 5; the filaments, or some of them, woolly 94

POLEMONIACEÆ.—Style 3-cleft. Corolla salver-shaped, with a long tube. Pod 3-celled, few-seeded; seeds small 109

CONVOLVULACEÆ.—Style 2-cleft. Pod 2-celled, generally 4-seeded; seeds large. Chiefly twining or trailing plants 109

SOLANACEÆ.—Style single. Pod or berry 2-celled, many-seeded 110

** * * * Stamens fewer than the lobes of the corolla; the corolla mostly irregular or 2-lipped.*

LABIATÆ.—Ovary 4-lobed around the base of the style. Stamens 4 and didynamous, or occasionally only 2 with anthers. Stem square .. 100

VERBENACEÆ.—Ovary 4-celled, but not lobed; the style rising from the apex. *Or*, ovary 1-celled and 1-seeded. Stamens didynamous 99

LENTIBULACEÆ.—Aquatic. Stamens 2. Ovary 1-celled, with a free central placenta 93

OROBANCHACEÆ.—Parasitic herbs, without green foliage. Ovary 1-celled, with many seeds on the walls. Stamens didynamous 94

SCROPHULARIACEÆ.—Ovary 2-celled, with many seeds. Stamens didynamous, or only 2 94

III. APETALOUS DIVISION.

Corolla (and sometimes calyx also) wanting.

1. Flowers not in catkins.

* *Calyx and corolla both wanting.*

SAURURACEÆ.—Flowers white, in a dense terminal spike, nodding at the end. Carpels 6 or 4, nearly separate 124

CERATOPHYLLACEÆ.—Immersed aquatics, with whorled finely dissected leaves. Flowers monœcious 124

* * *Calyx superior (i.e., adherent to the ovary).*

SAXIFRAGACEÆ.—Small, smooth herbs, with inconspicuous greenish-yellow flowers. Stamens twice as many as the calyx-lobes, on a conspicuous disk 16

HALORAGEÆ.—Aquatics. Leaves finely dissected or linear. Stamens 1-8. Ovary 4-lobed or (Hippuris) 1-celled. 49

ONAGRACEÆ.—Herbs, in ditches. Stamens 4. Ovary 4-celled, 4-sided 45

ARISTOLOCHIACEÆ.—Calyx 3-lobed, dull purple inside. Ovary 6-celled 116

SANTALACEÆ.—Low plants with greenish-white flowers in terminal clusters. Calyx-tube prolonged, and forming a neck to the 1-celled nut-like fruit 124

ELÆAGNACEÆ.—Shrubs with scurfy leaves. Flowers dioecious. Calyx 4-parted, in the fertile flowers apparently adherent to the ovary, and becoming fleshy in fruit 123

* * * *Calyx inferior (plainly free from the ovary).*

+ *Ovaries more than one and separate from each other.*

RANUNCULACEÆ.—Calyx present, colored and petal-like. Achenes containing several seeds, or only one 2

RUTACEÆ.—Prickly shrubs, with compound transparent-dotted leaves, and dioecious flowers ... 27

+-+ *Ovary only one, but with more than one cell.*

CRASSULACEÆ.—Herbs, in wet places. Pod 5-celled and 5-horned 48

PHYTOLACCACEÆ.—Herbs. Ovary 10-celled and 10-seeded 116

EUPHORBIACEÆ.—Herbs. Ovary 3-celled, 3-lobed, protruded on a long pedicel. Juice milky ... 125

SAPINDACEÆ.—Trees. Ovary 2-celled and 2-lobed. Fruit two 1-seeded samaras joined together. Flowers polygamous 31

RHAMNACEÆ.—Shrubs. Ovary 3-celled and 3-seeded; forming a berry 29

FICOIDEÆ.—Prostrate herbs with whorled leaves. Ovary 3-celled, many-seeded 52

URTICACEÆ.—Trees. Leaves simple. Ovary 2-celled, but fruit a 1-seeded samara winged all round. Stigmas 2 127

+-+-+ *Ovary only one, 1-celled and 1-seeded.*

POLYGONACEÆ.—Herbs. Stipules sheathing the stem at the nodes 119

URTICACEÆ.—Herbs. Stigma 1. Flowers monœcious or dioecious, in spikes or racemes. *No* chaff-like bracts among the flowers. *Or*, Stigmas 2; leaves palmately-compound ..... 1[illegible]

AMARANTACEÆ.—Herbs. Flowers greenish or reddish, in spikes, *with chaff-like bracts interspersed*. Stigmas 2 118

CHENOPODIACEÆ.—Herbs. Flowers greenish, in spikes. *No chaff-like bracts.* Stigmas 2 116

OLEACEÆ.—Trees. *Leaves pinnately-compound.* Fruit a 1-seeded samara 115

URTICACEÆ.—Trees. *Leaves simple.* Fruit a 1-seeded samara winged all round, or a drupe. 127

LAURACEÆ.—Trees or shrubs. Flowers dioecious. Sepals 6, petal-like. Stamens 9, opening by uplifting valves 122

THYMELEACEÆ.—Shrubs with leather-like bark, and jointed branchlets. Flowers perfect, preceding the leaves. Style thread-like 123

B. Flowers in catkins.

* *Sterile or staminate flowers only in catkins.*

JUGLANDACEÆ.—Trees with pinnate leaves. Fruit a nut with a husk 130

CUPULIFERÆ.—Trees with simple leaves. Fruit one or more nuts surrounded by an involucre which forms a scaly cup or bur 131

* * *Both sterile and fertile flowers in catkins, or catkin-like heads.*

SALICACEÆ.—Shrubs or low trees. Ovary 1-celled, many-seeded; seeds tufted with down at one end 136

PLATANACEÆ.—Large trees. *Stipules sheathing the branchlets.* The flowers in heads 130

MYRICACEÆ.—Shrubs with resinous-dotted, usually fragrant, leaves. Fertile flowers one under each scale. Nutlets usually coated with waxy grains 134

BETULACEÆ.—Trees or shrubs. Fertile flowers 2 or 3 under each scale of the catkin. Stigmas 2, long and slender 135

SUB-CLASS II. GYMNOSPERMS.

Ovules and seeds naked, on the inner face of an open scale; or, in Taxus, without any scale, but surrounded by a ring-like disk which becomes red and berry-like in fruit.

CONIFERÆ.—Trees or shrubs, with resinous juice, and mostly awl-shaped or needle-shaped leaves. Fruit a cone, or occasionally berry-like 139

CLASS II. MONOCOTYLEDONS.

Distinguished ordinarily by having straight-veined leaves (though occasionally net-veined ones), and the parts of the flowers in threes, never in fives. Wood never forming rings, but interspersed in separate bundles throughout the stem. Cotyledon only 1.

I. SPADICEOUS DIVISION.

Flowers collected on a spadix, with or without a spathe or sheathing bract. Leaves sometimes net-veined.

ARACEÆ.—Herbs (either flag-like marsh-plants, or terrestrial,) with pungent juice, and simple or compound leaves, these sometimes net-veined. Spadix usually (but not always) accompanied by a spathe. Flowers either without a perianth of any kind, or with 4-6 sepals 143

TYPHACEÆ.—Aquatic or marsh plants, with linear straight-veined leaves erect or floating, and monœcious flowers. Heads of flowers cylindrical or globular, no spathe, and no floral envelopes 144

LEMNACEÆ.—Small aquatics, freely floating about 144

NAIADACEÆ.—Immersed aquatics. Stems branching and leafy. Flowers perfect, in spikes, generally on the surface 145

II. PETALOIDEOUS DIVISION.

Flowers not collected on a spadix, furnished with a corolla-like, or occasionally herbaceous, perianth.

A. Perianth superior (adherent to the ovary).

* *Flowers dioecious or polygamous, regular.*

HYDROCHARIDACEÆ.—Aquatics. Pistillate flowers only above water; perianth of 6 pieces 148

DIOSCOREACEÆ.—Twiners, from knotted root-stocks. Leaves heart-shaped, net-veined. Pod with 3 large wings 157

* * *Flowers perfect.*

ORCHIDACEÆ.—Stamens 1 or 2, gynandrous. Flowers irregular 149

IRIDACEÆ.—Stamens 3 155

AMARYLLIDACEÆ.—Stamens 6. Flowers on a scape from a bulb 156

B. Perianth inferior (free from the ovary).

ALISMACEÆ.—Pistil apocarpous; carpels in a ring or head, leaves with distinct petiole and blade 147

SMILACEÆ.—Climbing plants, with alternate ribbed and net-veined petioled leaves. Flowers dioecious 157

Triglochin, in

ALISMACEÆ.—Rush-like marsh herbs. Flowers in a spike or raceme. Carpels when ripe splitting away from a persistent axis 147

LILIACEÆ.—Perianth of similar divisions or lobes, mostly 6, but in one case 4. One stamen in front of each division, the stamens similar.... 158

Trillium, in

LILIACEÆ.—Perianth of 3 green sepals and three colored petals 158

PONTEDERIACEÆ.—Stamens 6, 3 long and 3 short. Perianth (blue or yellow) tubular, of 6 lobes. Aquatics 164

JUNCACEÆ.—Perianth glumaceous, of similar pieces 162

ERIOCAULONACEÆ.—In shallow water. Flowers in a small woolly head, at the summit of a 7-angled scape. Leaves in a tuft at the base... 165

III. GLUMACEOUS DIVISION.

Flowers without a true perianth, but subtended by thin scales called glumes.

CYPERACEÆ.—Sheaths of the leaves not split..... 165

GRAMINEÆ.—Sheaths of the leaves split on the side away from the blade 168

SERIES II. CRYPTOGAMS.

Plants without stamens and pistils, reproducing themselves by spores instead of seeds.

CLASS III. PTERIDOPHYTES.

Stems containing vascular as well as cellular tissue.

FILICES.—Spores produced on the fronds 174

EQUISETACEÆ.—Spores produced on the under side of the shield-shaped scales of a terminal spike or cone 181

LYCOPODIACEÆ.—Spore-cases produced in the axils of the simple leaves or bracts 182

ILLUSTRATIVE EXAMPLES

OF

PLANT DESCRIPTION.

A few examples of the method of filling plant schedules are given in the pages which immediately follow. They are intended to be suggestive rather than to be implicitly followed. Teachers will use their own judgment as to the degree of elaboration which will be aimed at in any particular case, as a good deal must depend upon the stage of the pupils' knowledge.

PLANT SCHEDUDLE. NO.

ROOT.	Origin.....*Primary.*	**LEAF.**	Division.....*Simple.*
	Form.....*Tap, long and stout.*		Position.....*Cauline.*
	Colour.....*White or whitish.*		Arrangement...*Alternate.*
	Duration....*Biennial or perennial.*		Stipulation.....*Stipulate.*
	Position.....*Subterranean.*		Insertion.....*Petiolate; petioles very long.*
STEM.	Class.....*Dicotyledonous.*		Outline.....*Round-kidney-shaped.*
	Attitude.....*Ascending or procumbent.*		No. of leaflets, if any..*None.*
	Texture.....*Herbaceous.*		*Texture.....*Thickish.*
	Position.....*Aerial.*		*Colour.....*Green both sides.*
	Shape.....*Cylindrical.*		*Size.....*One to three inches across.*
	Juice.....*Mucilaginous.*		*Venation.....*Palmately net-veined.*
	Branching...*Stems simple, often tufted.*		*Margin.....*Slightly lobed and crenate.*
	Height.....*One to two feet.*		*Apex.....*Obtuse.*
	Duration....*Dying to the ground annually.*		*Base.....*Deeply cordate.*
	Surface.....*Pubescent.*		*Surface.....*Pubescent.*

*Applicable to leaflets if leaf is compound.

INFLORESCENCE. Mode.....*Racemose* Variety.....*One or two flowers in each axil.*

THE FLOWER.

ORGAN.	NO.	COHESION.	ADHESION.	NOTES ON FORM, ÆSTIVATION, COLOUR, ETC.
Perianth. *Leaves.*		NOTE.—This space need	not be used except for	Monocotyledons.
Calyx. *Sepals.*	5	*Gamosepalous.*	*Inferior.*	*An epicalyx of three bracts. Calyx valvate, persistent.*
Corolla. *Petals.*	5	*Polypetalous.*	*Hypogynous.*	*Petals white or pinkish, obcordate, ½ inch long, convolute in the bud.*
Stamens. *Filaments.*	∞	*Monadelphous.*	*Hypogynous.*	*Tube of stamens united with the base of the corolla. Anthers 1-celled.*
Anthers.	∞			
Pistil. *Stigmas.*	∞	*Syncarpous.*	*Superior.*	*Carpels in a ring, as many as the styles, 1-seeded.*
Styles.	∞			
Carpels.	∞			
Ovary-cells.	∞			

FRUIT.

Kind.....*Dry, indehiscent.*

Variety.....*Schizocarp, breaking up into 1-seeded closed carpels.*

Dehiscence.....*Indehiscent.*

No. of Seeds.....*As many as the carpels.*

Description of Seed..*Kidney-shaped, cotyledons crumpled, little albumen.*

FLORAL DIAGRAM.

CLASSIFICATION, &c.

SERIES.....*Phanerogams.*

CLASS.....*Angiosperms.*

SUB-CLASS.....*Dicotyledons.*

DIVISION .....*Polypetalous.*

Order.....*Malvaceæ.*

Genus.....*Malva.*

Species.....*Rotundifolia.*

Botanical Name .....*Malva rotundifolia.*

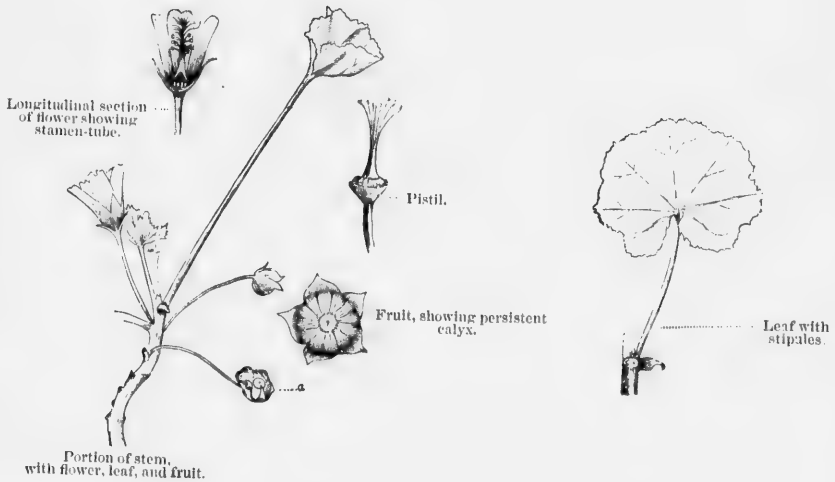
Popular Name.....*Round-leaved Mallow.*

Habitat .....*Roadsides and cultivated soil.*

Where found .....*Roadside, North Toronto.*

Date of collection.....*September 20th, 1894.*

DRAWINGS, &c.



PLANT SCHEDUDLE.

NO.

ROOT.
Origin.....*Secondary.*
Form.....*Fibrous.*
Colour .....*Whitish.*
Duration ....*Perennial.*
Position .....*Subterranean.*

STEM.
Class.....*Monocotyledonous; a bulb.*
Attitude.....
Texture .....*Herbaceous.*
Position .....*Deep in the ground.*
Shape .....*Mostly oblong; small.*
Juice.....*Colourless.*
Branching...*None.*
Height .....
Duration ....*Perennial.*
Surface.....

LEAF.
Division .....*Simple.*
Position .....*Radical.*
Arrangement...*Alternate.*
Stipulation.....*Exstipulate.*
Insertion.....*Petioles sheathing the scape.*
Outline .....*Oblong-lanceolate.*
No. of leaflets, if any..*None.*
*Texture.....*Thickish and soft.*
*Colour.....*Green, mottled with purple above.*
*Size .....*Three to five inches long.*
*Venation .....*Straight-veined.*
*Margin .....*Entire.*
*Apex .....*Acute.*
*Base.....*Tapering.*
*Surface .....*Smooth and shining.*

* Applicable to leaflets if leaf is compound.

INFLORESCENCE. Mode.....*Terminal.* Variety.....*Solitary.*

THE FLOWER.

ORGAN.	No.	COHESION.	ADHESION.	NOTES ON FORM, ÆSTIVATION, COLOUR, ETC.
Perianth. *Leaves.*	6	*Polyphyllous.*	*Inferior.*	*Divisions spreading, lanceolate, yellow, purple-spotted, an inch long.*
Calyx. *Sepals.*				
Corolla. *Petals.*				
Stamens.	6	*Hexandrous.*	*Hypogynous.*	*Stamens opposite the divisions of the perianth.*
Filaments.	6			
Anthers.	6			
Pistil.		*Syncarpous.*	*Superior.*	*Ovary narrowed at the base. Style club-shaped. Stigma 3-lobed.*
Stigmas.	1			
Styles.	1			
Carpels.	3			
Ovary-cells.	3			

FRUIT.
Kind .....*Dry; dehiscent.*
Variety.....*Capsule.*
Dehiscence .....*Loculicidal.*
No. of Seeds .....*Many.*
Description of Seed..*Ovoid, with membranaceous tip. Albuminous.*

FLORAL DIAGRAM.

CLASSIFICATION, &c.

SERIES.. .....*Phanerogams.*

CLASS.....*Angiosperms.*

SUB-CLASS.....*Monocotyledons.*

DIVISION.....*Petaloidrous.*

Order..... *Liliaceæ.*

Genus.. .....*Erythronium.*

Species .....*Americanum.*

Botanical Name.....*Erythronium Americanum.*

Popular Name.....*Dog's-tooth Violet.*

Habitat .....*Copses.*

Where found .....*High Park, Toronto.*

Date of collection.....*May 3rd, 1894.*

DRAWINGS, &c.

sheathing petiole,
the scape within

bulb (coated)

Pistil.

cross-section
of ovary.

NOTE.—*This plant sends up a scape, 5 or 6 inches high, which bears a single nodding flower. The leaves are two in number.*

COMPOSITES. **PLANT SCHEDUDLE.** NO. .....

ROOT.
- Origin.....*Secondary.*
- Form.....*Fibrous.*
- Colour .....*Brownish.*
- Duration ....*Perennial.*
- Position .....*Subterranean.*

STEM.
- Class.....*Dicotyledonous.*
- Attitude.....*Erect.*
- Texture .....*Herbaceous.*
- Position .....*Aërial, from a rootstock.*
- Shape .....*Cylindrical, slightly grooved.*
- Juice.....*Colourless.*
- Branching...*Usually none.*
- Height .....*About 18 inches.*
- Duration ....*Rhizome perennial; aërial stem annual.*
- Surface.....*Smooth, or nearly so.*

LEAF.
- Division ...*Simple.*
- Position ...*Radical and cauline.*
- Arrangement..*Alternate.*
- Stipulation. *Exstipulate.*
- Insertion...*Lower petiolate; upper sessile.*
- Outline ....*Lower spathulate; upper linear.*
- No. of leaflets, if any..*None.*
- *Texture....*Rather thick.*
- *Colour.....*Green both sides.*
- *Size .....*1–1½ inches long.*
- *Venation ..*Pinnately net-veined.*
- *Margin ....*Radical crenate; cauline serrate.*
- *Apex .....*Obtuse.*
- *Base .....*Lower tapering; upper clasping.*
- *Surface ....*Glabrous.*

* Applicable to leaflets if leaf is compound.

INFLORESCENCE, &c.

HEADS.
- Arrangement.....*Terminal, solitary.*
- Kind.....*Radiate.*
- Size.....*1½–2 inches across.*

***RAY-FLORETS.**
- Number.....*Many.*
- Colour .....*White*
- Shape.....*Linear-oblong.*
- Kind.....*Pistillate.*
- Pappus.....*Wanting.*

***DISK-FLORETS.**
- Number.....*Very many.*
- Colour .....*Yellow.*
- Shape.....*Tubular, slightly compressed.*
- Kind.....*Perfect.*
- Pappus.....*Wanting.*

RECEPTACLE.
- Form .....*Flattish, or slightly convex.*
- Surface .....*Naked.*

INVOLUCRE.
- Form .....*Broad and flat.*
- Rows of Scales.....*About four.*
- Form of Scales.....*Lanceolate.*
- Texture of Scales ....*With scarious margins.*
- Arrangement.....*Imbricated.*

ACHENES.
- Form .....*Nearly cylindrical.*
- Surface.....*Striate or ribbed.*
- Colour .....*Whitish or grayish.*

SEED.
Exalbuminous.

* If florets are all alike give particulars under heading Disk-florets.

THE FLOWER.

Organ.	No.	Cohesion.	Adhesion.	Floral Diagram.
Calyx. *Sepals.*	5	*Gamosepalous.*	*Superior.*	
Corolla. *Petals.*	5	*Gamopetalous.*	*Epigynous.*	
Stamens. *Filaments.* *Anthers.*	5 5 5	*Syngenesious.*	*Epipetalous.*	
Pistil. *Stigmas.* *Styles.* *Carpels.* *Ovary-cells.*	2 1 2 1	*Synearpous.*	*Inferior.*	

CLASSIFICATION, &c.

SERIES.....*Phanerogams.*

CLASS.....*Angiosperms.*

SUB-CLASS.....*Dicotyledons.*

DIVISION.....*Gamopetalous.*

Order.....*Compositæ.*

Genus.....*Leucanthemum.*

Species.....*Vulgare.*

Botanical Name.....*Leucanthemum vulgare.*

Popular Name.....*Ox-eye Daisy.*

Habitat.....*Fields and pastures.*

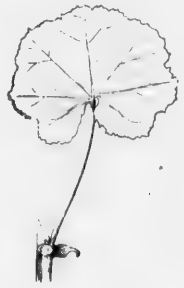
Where found.....*Barrie.*

Date of collection.....*August 10th, 1862.*

DRAWINGS, &c.

LEAF SCHEDULES.

Leaf of Round-leaved Mallow.

Description.	Drawings.
Division ..... *Simple.*	
Position ..... *Cauline.*	
Arrangement ..... *Alternate.*	
Insertion ..... *Petiolate.*	
Stipulation ..... *Stipulate.*	
Outline ..... *Orbicular.*	
No. of leaflets, if any .. *None.*	
*Texture ..... *Thickish.*	
*Colour ..... *Dark green both sides.*	
*Size ..... *1 to 3 inches across.*	
*Venation ..... *Palmately net-veined.*	
*Margin ..... *Slightly lobed and crenate.*	
*Apex ..... *Obtuse.*	
*Base ..... *Deeply cordate.*	
*Surface ..... *Minutely pubescent both sides.*	

Applicable to leaflets if leaf is compound.

Leaf of Red Clover.

Division ..... *Compound; palmate.*	
Position ..... *Cauline.*	
Arrangement ..... *Alternate.*	
Insertion ..... *Petiolate.*	
Stipulation ..... *Stipulate; stipules united with petiole.*	
Outline ..... *Deltoid, or triangular.*	
No. of leaflets, if any .. *3.*	
*Texture ..... *Rather thin and soft.*	
*Colour ..... *Green, with a white spot above.*	
*Size ..... *1 to 1½ inches long.*	
*Venation ..... *Pinnately net-veined.*	
*Margin ..... *Entire or obscurely serrate.*	
*Apex ..... *Generally emarginate.*	
*Base ..... *Mostly obtuse.*	
*Surface ..... *Pubescent and ciliate.*	

* Applicable to leaflets if leaf is compound.

DESCRIPTIVE SCHEDULES.

PLANT SCHEDULE.

No.

ROOT.
- Origin
- Form
- Colour
- Duration
- Position

STEM.
- Class
- Attitude
- Texture
- Position
- Shape
- Juice
- Branching
- Height
- Duration
- Surface

LEAF.
- Division
- Position
- Arrangement
- Stipulation
- Insertion
- Outline
- No. of leaflets, if any
- *Texture
- *Colour
- *Size
- *Venation
- *Margin
- *Apex
- *Base
- *Surface

* Applicable to leaflets if leaf is compound.

INFLORESCENCE. Mode

Variety

THE FLOWER.

ORGAN.	No.	COHESION.	ADHESION.	NOTES ON FORM, ÆSTIVATION, COLOUR, ETC.
Perianth. *Leaves.*				
Calyx. *Sepals.*				
Corolla. *Petals.*				
Stamens. *Filaments.* *Anthers.*				
Pistil. *Stigmas.* *Styles.* *Carpels.* *Ovary-cells.*				

FRUIT.
- Kind
- Variety
- Dehiscence
- No. of Seeds
- Description of Seed

FLORAL DIAGRAM.

CLASSIFICATION, &c.

SERIES	Botanical Name
CLASS	Popular Name
SUB-CLASS	Habitat
DIVISION	Where found
Order	Date of collection
Genus	
Species	

DRAWINGS, &c.

PLANT SCHEDULE.

No. .....

ROOT.
- Origin .....
- Form .....
- Colour .....
- Duration .....
- Position .....

STEM.
- Class .....
- Attitude .....
- Texture .....
- Position .....
- Shape .....
- Juice .....
- Branching .....
- Height .....
- Duration .....
- Surface .....

LEAF.
- Division .....
- Position .....
- Arrangement .....
- Stipulation .....
- Insertion .....
- Outline .....
- No. of leaflets, if any .....
- *Texture .....
- *Colour .....
- *Size .....
- *Venation .....
- *Margin .....
- *Apex .....
- *Base .....
- *Surface .....

* Applicable to leaflets if leaf is compound.

INFLORESCENCE. Mode ..... Variety .....

THE FLOWER.

ORGAN.	No.	COHESION.	ADHESION.	NOTES ON FORM, ÆSTIVATION, COLOUR, ETC.
Perianth. *Leaves.*				
Calyx. *Sepals.*				
Corolla. *Petals.*				
Stamens. *Filaments.* *Anthers.*				
Pistil. *Stigmas.* *Styles.* *Carpels.* *Ovary-cells.*				

FRUIT.
- Kind .....
- Variety .....
- Dehiscence .....
- No. of Seeds .....
- Description of Seed .....

FLORAL DIAGRAM.

CLASSIFICATION, &c.

SERIES.

CLASS.

SUB-CLASS.

DIVISION.

Order.

Genus.

Species.

Botanical Name.

Popular Name.

Habitat.

Where found.

Date of collection.

DRAWINGS, &c.

PLANT SCHEDULE.

NO. .....

ROOT. Origin
Form
Colour
Duration
Position

STEM. Class
Attitude
Texture
Position
Ships
Juice
Branching
Height
Duration
Surface

LEAF. Division
Position
Arrangement
Stipulation
Insertion
Outline
No. of leaflets, if any
*Texture
*Colour
*Size
*Venation
*Margin
*Apex
*Base
*Surface

* Applicable to leaflets if leaf is compound.

INFLORESCENCE. Mode
Variety

THE FLOWER.

ORGAN.	No.	COHESION.	ADHESION.	NOTES ON FORM, ÆSTIVATION, COLOUR, ETC.
Perianth. *Leaves.*				
Calyx. *Sepals.*				
Corolla. *Petals.*				
Stamens. *Filaments.* *Anthers.*				
Pistil. *Stigmas.* *Styles.* *Carpels.* *Ovary-cells.*				

FRUIT. Kind
Variety
Dehiscence
No. of Seeds
Description of Seed

FLORAL DIAGRAM.

CLASSIFICATION, &c.

SERIES

CLASS

SUB-CLASS

DIVISION

Order

Genus

Species

Botanical Name

Popular Name

Habitat

Where found

Date of collection

DRAWINGS, &c.

PLANT SCHEDULE.

NO. .....

ROOT.
Origin .....
Form .....
Colour .....
Duration .....
Position .....

STEM.
Class .....
Attitude .....
Texture .....
Position .....
Shape .....
Juice .....
Branching .....
Height .....
Duration .....
Surface .....

LEAF.
Division .....
Position .....
Arrangement .....
Stipulation .....
Insertion .....
Outline .....
No. of leaflets, if any .....
*Texture .....
*Colour .....
*Size .....
*Venation .....
*Margin .....
*Apex .....
*Base .....
*Surface .....

* Applicable to leaflets if leaf is compound.

INFLORESCENCE. Mode ..... Variety .....

THE FLOWER.

ORGAN.	No.	COHESION.	ADHESION.	NOTES ON FORM, ÆSTIVATION, COLOUR, ETC.
Perianth. *Leaves.*				
Calyx. *Sepals.*				
Corolla. *Petals.*				
Stamens. *Filaments.* *Anthers.*				
Pistil. *Stigmas.* *Styles.* *Carpels.* *Ovary-cells.*				

FRUIT.
Kind .....
Variety .....
Dehiscence .....
No. of Seeds .....
Description of Seed .....

FLORAL DIAGRAM.

CLASSIFICATION, &c.

SERIES

CLASS

SUB-CLASS

DIVISION

Order

Genus

Species

Botanical Name

Popular Name

Habitat

Where found

Date of collection

DRAWINGS, &c.

PLANT SCHEDULE.

No. .....

ROOT.
- Origin
- Form
- Colour
- Duration
- Position

STEM.
- Class
- Attitude
- Texture
- Position
- Shape
- Juice
- Branching
- Height
- Duration
- Surface

LEAF.
- Division
- Position
- Arrangemen
- Stipulation
- Insertion
- Outline
- No. of leaflets, if any
- *Texture
- *Colour
- *Size
- *Venation
- *Margin
- *Apex
- *Base
- *Surface

* Applicable to leaflets if leaf is compound.

INFLORESCENCE. Mode ..... Variety

THE FLOWER.

Organ.	No.	Cohesion.	Adhesion.	Notes on Form, Æstivation, Colour, etc.
Perianth. *Leaves.*				
Calyx. *Sepals.*				
Corolla. *Petals.*				
Stamens. *Filaments.* *Anthers.*				
Pistil. *Stigmas.* *Styles.* *Carpels.* *Ovary-cells.*				

FRUIT.
- Kind
- Variety
- Dehiscence
- No. of Seeds
- Description of Seed

Floral Diagram.

ASSIFICATION, &c.

SERIES ..... | Botanical Name

CLASS | Popular Name

SUB-CLASS ..... | Habitat

DIVISION ..... | Where found

Order ..... | Date of collection

Genus

Species

DRAWINGS, &c.

PLANT SCHEDULE.

NO.

ROOT.
Origin
Form
Colour
Duration
Position

STEM.
Class
Attitude
Texture
Position
Shape
Juice
Branching
Height
Duration
Surface

LEAF.
Division
Position
Arrangement
Stipulation
Insertion
Outline
No. of leaflets, if any
*Texture
*Colour
*Size
*Venation
*Margin
*Apex
*Base
*Surface

* Applicable to leaflets if leaf is compound.

INFLORESCENCE. Mode Variety

THE FLOWER.

ORGAN.	NO.	COHESION.	ADHESION.	NOTES ON FORM, ÆSTIVATION, COLOUR, ETC.
Perianth. *Leaves.*				
Calyx. *Sepals.*				
Corolla. *Petals.*				
Stamens. *Filaments.* *Anthers.*				
Pistil. *Stigmas.* *Styles.* *Carpels.* *Ovary-cells.*				

FRUIT.
Kind
Variety
Dehiscence
No. of Seeds
Description of Seed

FLORAL DIAGRAM.

CLASSIFICATION, &c.

SERIES	Botanical Name
CLASS	Popular Name
SUB-CLASS	Habitat
DIVISION	Where found
Order	Date of collection
Genus	
Species	

DRAWINGS, &c.

PLANT SCHEDULE.

No.

ROOT.
- Origin
- Form
- Colour
- Duration
- Position

STEM.
- Class
- Attitude
- Texture
- Position
- Shape
- Juice
- Branching
- Height
- Duration
- Surface

LEAF.
- Division
- Position
- Arrangement
- Stipulation
- Insertion
- Outline
- No. of leaflets, if any
- *Texture
- *Colour
- *Size
- *Venation
- *Margin
- *Apex
- *Base
- *Surface

* Applicable to leaflets if leaf is compound.

INFLORESCENCE. Mode

Variety

THE FLOWER.

ORGAN.	No.	COHESION.	ADHESION.	NOTES ON FORM, ÆSTIVATION, COLOUR, ETC.
Perianth. *Leaves.*				
Calyx. *Sepals.*				
Corolla. *Petals.*				
Stamens. *Filaments.* *Anthers.*				
Pistil. *Stigmas.* *Styles.* *Carpels.* *Ovary-cells.*				

FRUIT.
- Kind
- Variety
- Dehiscence
- No. of Seeds
- Description of Seed

FLORAL DIAGRAM.

CLASSIFICATION, &c.

SERIES	Botanical Name
CLASS	Popular Name
SUB-CLASS	Habitat
DIVISION	Where found
Order	Date of collection
Genus	
Species	

DRAWINGS, &c.

PLANT SCHEDULE.

No. .....

ROOT.
- Origin
- Form
- Colour
- Duration
- Position

STEM.
- Class
- Attitude
- Texture
- Position
- Shape
- Juice
- Branching
- Height
- Duration
- Surface

LEAF.
- Division
- Position
- Arrangement
- Stipulation
- Insertion
- Outline
- No. of leaflets, if any
- *Texture
- *Colour
- *Size
- *Venation
- *Margin
- *Apex
- *Base
- *Surface

* Applicable to leaflets if leaf is compound.

INFLORESCENCE. Mode ..... Variety .....

THE FLOWER.

ORGAN.	No.	COHESION.	ADHESION.	NOTES ON FORM, ÆSTIVATION, COLOUR, ETC.
Perianth. *Leaves.*				
Calyx. *Sepals.*				
Corolla. *Petals.*				
Stamens. *Filaments.* *Anthers.*				
Pistil. *Stigmas.* *Styles.* *Carpels.* *Ovary-cells.*				

FRUIT.
- Kind
- Variety
- Dehiscence
- No. of Seeds
- Description of Seed

FLORAL DIAGRAM.

CLASSIFICATION

SERIES

CLASS

SUB-CLASS

DIVISION

Order

Genus

Species

Botanical Name

Popular Name

Habitat

Where found

Date of collection

DRAWINGS, &c.

PLANT SCHEDULE.

No.

ROOT. Origin
Form
Colour
Duration
Position

STEM. Class
Attitude
Texture
Position
Shape
Juice
Branching
Height
Duration
Surface

LEAF. Division
Position
Arrangement
Stipulation
Insertion
Outline
No. of leaflets, if any
Texture
*Colour
*Size
*Venation
*Margin
*Apex
*Base
*Surface

* Applicable to leaflets if leaf is compound.

INFLORESCENCE. Mode
Variety

THE FLOWER.

Organ.	No.	Cohesion.	Adhesion.	Notes on Form, Æstivation, Colour, etc.
Perianth. *Leaves.*				
Calyx. *Sepals.*				
Corolla. *Petals.*				
Stamens. *Filaments.* *Anthers.*				
Pistil. *Stigmas.* *Styles.* *Carpels.* *Ovary-cells.*				

FRUIT. Kind
Variety
Dehiscence
No. of Seeds
Description of Seed

Floral Diagram.

CLASSIFICATION, &c.

SERIES

CLASS

SUB-CLASS

DIVISION

Order

Genus

Species

Botanical Name

Popular Name

Habitat

Where found

Date of collection

DRAWINGS, &c.

PLANT SCHEDULE.

No.....

ROOT.
- Origin
- Form
- Colour
- Duration
- Position

STEM.
- Class
- Attitude
- Texture
- Position
- Shape
- Juice
- Branching
- Height
- Duration
- Surface

LEAF.
- Division
- Position
- Arrangement
- Stipulation
- Insertion
- Outline
- No. of leaflets, if any
- *Texture
- *Colour
- *Size
- *Venation
- *Margin
- *Apex
- *Base
- *Surface

* Applicable to leaflets if leaf is compound.

INFLORESCENCE. Mode..... Variety

THE FLOWER.

ORGAN.	No.	COHESION.	ADHESION.	NOTES ON FORM, ÆSTIVATION, COLOUR, ETC.
Perianth. *Leaves.*				
Calyx. *Sepals.*				
Corolla. *Petals.*				
Stamens. *Filaments.* *Anthers.*				
Pistil. *Stigmas.* *Styles.* *Carpels.* *Ovary-cells.*				

FRUIT.
- Kind
- Variety
- Dehiscence
- No. of Seeds
- Description of Seed

FLORAL DIAGRAM.

CLASSIFICATION, &c.

SERIES

CLASS

SUB-CLASS

DIVISION

Order

Genus

Species

Botanical Name

Popular Name

Habitat

Where found

Date of collection

DRAWINGS, &c.

PLANT SCHEDULE.

No. .....

ROOT.
- Origin
- Form
- Colour
- Duration
- Position

STEM.
- Class
- Attitude
- Texture
- Position
- Shape
- Juice
- Branching
- Height
- Duration
- Surface

LEAF.
- Division
- Position
- Arrangement
- Stipulation
- Insertion
- Outline
- No. of leaflets, if any
- *Texture
- *Colour
- *Size
- *Venation
- *Margin
- *Apex
- *Base
- *Surface

* Applicable to leaflets if leaf is compound.

INFLORESCENCE. Mode ..... Variety .....

THE FLOWER.

ORGAN.	No.	COHESION.	ADHESION.	NOTES ON FORM, ÆSTIVATION, COLOUR, ETC.
Perianth. *Leaves.*				
Calyx. *Sepals.*				
Corolla. *Petals.*				
Stamens. *Filaments.* *Anthers.*				
Pistil. *Stigmas.* *Styles.* *Carpels.* *Ovary-cells.*				

FRUIT.
- Kind
- Variety
- Dehiscence
- No. of Seeds
- Description of Seed

FLORAL DIAGRAM.

CLASSIFICATION, &c.

SERIES.....

CLASS .....

SUB-CLASS .....

DIVISION .....

Order.....

Genus .....

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FLORAL DIAGRAM.

CLASSIFICATION, &c.

SERIES	Botanical Name
CLASS	Popular Name
SUB-CLASS	Habitat
DIVISION	Where found
Order	Date of collection
Genus	
Species	

DRAWINGS, &c.

PLANT SCHEDULE.

No.

ROOT.
Origin
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Colour
Duration
Position

STEM.
Class
Attitude
Texture
Position
Shape
Juice
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Height
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INFLORESCENCE. Mode Variety

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FRUIT.
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No. of Seeds
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Floral Diagram.

CLASSIFICATION, &c.

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DRAWINGS, &c.

PLANT SCHEDULE.

No.

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STEM. Class

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Surface

LEAF. Division

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FRUIT. Kind

Variety

Dehiscence

No. of Seeds

Description of Seed

Floral Diagram.

CLASSIFICATION, &c.

SERIES..... Botanical Name

CLASS..... Popular Name

SUB-CLASS..... Habitat

DIVISION..... Where found

Order..... Date of collection

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DRAWINGS, &c.

PLANT SCHEDULE.

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ROOT.
- Origin
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FLORAL DIAGRAM.

CLASSIFICATION, &c.

SERIES ..... | Botanical Name

CLASS ..... | Popular Name

SUB-CLASS ..... | Habitat

DIVISION ..... | Where found

Order ..... | Date of collection

Genus

Species

DRAWINGS, &c.

PLANT SCHEDULE.

No. .....

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FLORAL DIAGRAM.

CLASSIFICATION, &c.

SERIES	Botanical Name
CLASS	Popular Name
SUB-CLASS	Habitat
DIVISION	Where found
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DRAWINGS, &c.

PLANT SCHEDULE.

No. .....

ROOT.
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- Colour
- Duration
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Floral Diagram.

CLASSIFICATION, &c.

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DRAWINGS, &c.

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FLORAL DIAGRAM.

CLASSIFICATION, &c.

SERIES	Botanical Name
CLASS	Popular Name
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DIVISION	Where found
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DRAWINGS, &c.

PLANT SCHEDULE.

NO.

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Origin
Form
Colour
Duration
Position

STEM.
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FLORAL DIAGRAM.

CLASSIFICATION, &c.

SERIES

CLASS

SUB-CLASS

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Order

Genus

Species

Botanical Name

Popular Name

Habitat

Where found

Date of collection

DRAWINGS, &c.

COMPOSITES. PLANT SCHEDULE. NO.

ROOT.
- Origin
- Form
- Colour
- Duration
- Position

STEM.
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- *Surface

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INFLORESCENCE, &c.

HEADS.
- Arrangement
- Kind
- Size

***RAY-FLORETS.**
- Number
- Colour
- Shape
- Kind
- Pappus

***DISK-FLORETS.**
- Number
- Colour
- Shape
- Kind
- Pappus

RECEPTACLE.
- Form
- Surface

INVOLUCRE.
- Form
- Rows of scales
- Form of scales
- Texture of scales
- Arrangement

ACHENES.
- Form
- Surface
- Colour

SEED.

* If florets are all alike give particulars under heading Disk-florets.

THE FLOWER.

ORGAN.	No.	COHESION.	ADHESION.	FLORAL DIAGRAM.
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CLASSIFICATION, &c.

SERIES.....

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DRAWINGS, &c.

COMPOSITES. PLANT SCHEDULE. NO.

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DRAWINGS, &c.

COMPOSITES. PLANT SCHEDULE. NO.

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DRAWINGS, &c.

COMPOSITES. PLANT SCHEDULE. NO. .....

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DRAWINGS, &c.

COMPOSITES. PLANT SCHEDULE. NO.

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DRAWINGS, &c.

LEAF SCHEDULES.

LEAF OF .....

DESCRIPTION.	DRAWINGS.
Division	
Position	
Arrangement	
Insertion	
Stipulation	
Outline	
No. of leaflets, if any	
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*Venation	
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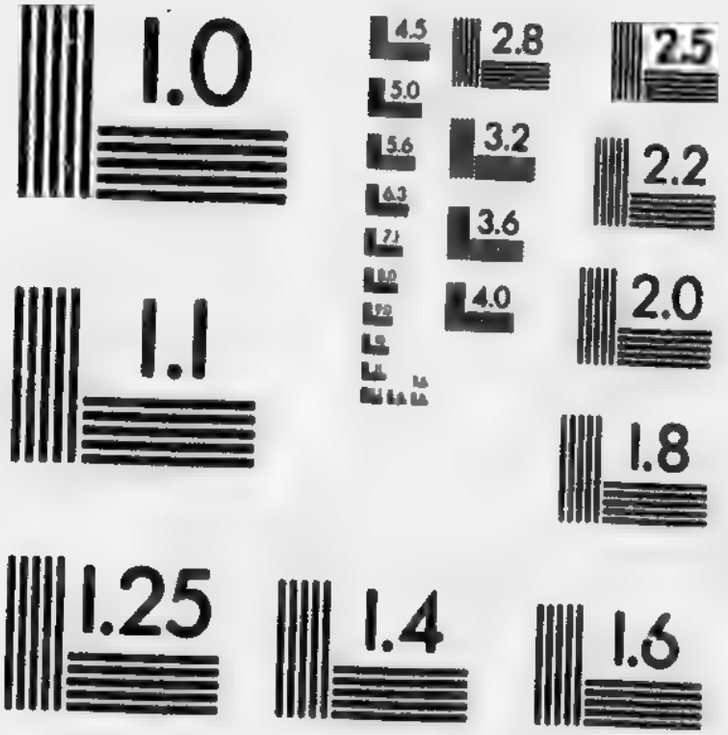
MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



APPLIED IMAGE Inc

1653 East Main Street
Rochester, New York 14609 USA
(716) 482 - 0300 - Phone
(716) 288 - 5989 - Fax

FLOWER SCHEDULES.

FLOWER OF

ORGAN.	No.	COHESION.	ADHESION.	NOTES ON FORM, ÆSTIVATION, COLOUR, ETC.
Perianth. *Leaves.*				
Calyx. *Sepals.*				
Corolla. *Petals.*				
Stamens. *Filaments.* *Anthers.*				
Pistil. *Stigmas.* *Styles.* *Carpels.* *Ovary-cells.*				

FRUIT.

Kind

Variety

Dehiscence

No. of Seeds

Description of Seed

FLORAL DIAGRAM.

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FLOWER SCHEDULES.

FLOWER OF

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Perianth. *Leaves.*				
Calyx. *Sepals.*				
Corolla. *Petals.*				
Stamens. *Filaments.* *Anthers.*				
Pistil. *Stigmas.* *Styles.* *Carpels.* *Ovary-cells.*				

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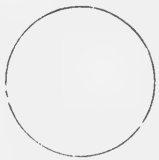

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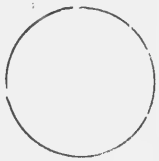

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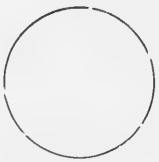

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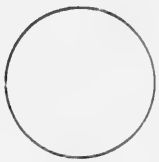

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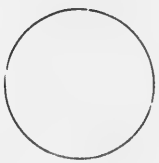

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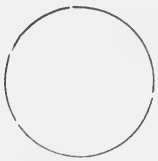

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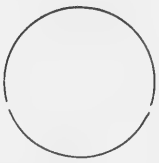

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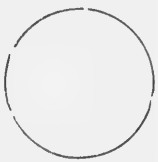

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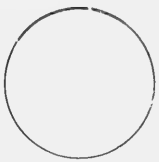

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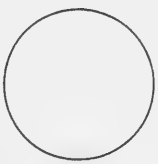

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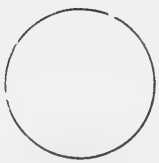

Diagram of.....

INDEX OF PLANTS.

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